MANUAL

ON

GROUNDWATER

AND

WELL-SINKING

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ACKNOWLEDGEMENTS.

I am returning..........the monograph on groundwater and well sinking operations in Hyderabad by Mr. D. V. Rao.

I consider it an excellent piece of work in which all aspects of groundwater are adequately examined and dealt with, *viz.*, the geological, engineering and medical. The author, being an Engineer would naturally do justice to the engineering aspect; but the fact that the geological portion is equally well treated speaks much for his mastery of the subject and the excellent co-operation he has secured.

I hope the author will have the monograph published sometime. It will be a useful publication to those working on similar problems in other parts of India, especially the drier places where the provision of good drinking water is of great importance.

DR. M. S. KRISHNAN,
M.A., Ph.D., A.R.C.S., D.I.C.,
Geological Survey of India.

MADRAS,
Dated 4-4-1945.

* * * *

I am glad to learn that the Well Sinking Manual is likely to be published shortly. Having had the opportunity of going through the Manual in detail and having had the advantage of knowing intimately the geology and the conditions of sub-surface water of the area covered therein, I wish to convey to you my sincerest congratulations for the comprehensive treatise you have written on well sinking in all its varied aspects. It is bound to interest not only Hyderabadis but everyone in South India and countries similarly situated who is engaged in geological or well sinking work.

I shall have no hesitation in commending the Manual as an excellent text-book for advanced students in geology and for those geologists who want to specialise in Hydrology. I am very glad to find that a very discriminating and eminent geologist like Dr. M. S. Krishnan who scrutinised it agrees with me.

Kindly send me without fail a manuscript copy of the Manual for my use in the University.

DR. C. MAHADEVAN,
M.A., D.SC., F.A.SC.,
Head of the Department of Natural Science and Professor of Geology, Andhra University, Waltair.

GUNTUR,
Dated 2-7-1945.

FOREWORD

Of the several elements essential for the survival of man, none occupies a higher place than water. But the mere availability of this fundamental element is not by itself sufficient to ensure man's progress, for if not controlled and harnessed scientifically to his needs, it may readily become a carrier of death and disease instead of a blessing to mankind. All civilised Governments, therefore, recognise the need for placing the provision of assured supplies of good water in the forefront of any policy for the improvement of the health of their peoples and the betterment of their standards of living. In no country is the problem of providing good water more pressing or more difficult of solution than in the vast rural areas of the Indian sub-continent.

In the vanguard of pioneers in the provision of good water for rural areas, the Government of Hyderabad occupies a proud and unique position. Realising early that private enterprise could never bring to the many thousands of villagers and hamlets of the State the inestimable boon of an adequate and sound water-supply, the Government of Hyderabad resolved upon a systematic plan for the provision of wells scientifically designed and constructed. As a first step towards the fulfilment of this policy, a Well Sinking Department was created in the State twenty years ago, charged with the task of making available in every village an assured source of good water for the inhabitants. The Department's activities commenced in the famine stricken area of Raichur District but subsequently the sphere of operations was extended to other neighbouring districts falling within the famine zone. Up-to-date, as a result of the Department's activities, over 3,000 wells have been sunk in four districts of the State, and the extension of the work to all areas in the Dominions has been approved by the Government of the State as a measure of first importance in Hyderabad's post-war plans.

The State's Well Sinking Department commenced its operations under the guidance of the late Capt. L. Munn, O.B.E. On his untimely death while still in the service of the State, the work of which he had so ably laid the foundations, was carried on by another enthusiast, Mr. D. V. Rao, B.Sc., (London), M.I.E., (India), F.R.S.A. (London), the author of the present Manual. Thanks to the energy and ability of Mr. Rao as Special Officer of the Well Sinking Department, substantial progress has been

made in implementing the State's policy in spite of numerous difficulties arising in recent years from the advent of the War.

Mr. Rao's " Manual on Ground Water and Well Sinking " is an important and valuable contribution to existing studies on the subject and throughout bears the imprint of long and careful research into the multifarious problems connected with the supply of water in rural areas. Mr. Rao's work has the advantage of being based not merely on theory, but on practical experience gained by the author personally in the field over a number of years and under all kinds of conditions. The present manual covers not only the theory and practice of village well construction, but deals also in detail with such allied matters as rural public-health, village afforestation and labour legislation, all of which have a direct bearing on the major problem of assuring the water needs of the peasantry. The " Manual " will be of particular assistance to engineers and others engaged on well sinking operations, and the exhaustive information on every aspect of well sinking which is incorporated in it will also be studied with interest and advantage, by the student and the administrator. Mr. Rao's treatise is a notable addition to Hyderabad scientific learning, and will be welcomed as a practical contribution to the solution of the important problem of water-supply by all Governments at whose disposal the author has so readily placed his many years of experience and research.

C.A.G. SAVIDGE, I.C.S.,
Officiating Revenue Member.

BEGUMPET,
Hyderabad-Dn.

INTRODUCTION.

The secular metabolic changes on our globe (and of the solar system as a whole) most of which are still obscure and unexplainable, have perhaps resulted at present in the slow regional aerial desiccation, bringing about, amongst other things, a serious diminution of rainfall in many places. This situation has been further aggravated by many imprudent activities and inactivities, the deforestation of many areas which has not only brought about, in its wake, the reduction in rainfall but also quick soil erosion and runoff, resulting in a depletion of both surface and underground water supplies.

The cumulative effect of these adverse features has given rise to urgent matters for very serious consideration. The insufficient and irregular rainfall mainfesting therefore, in Famine conditions as well as inadequate drinking water supplies due to lowering of groundwater in many areas of the State, resulted in many villages which were once flourishing centres, being deserted and the people migrating to other areas, to the agrarian discontent of others. Portions of them migrated ino the surrounding areas with loss in population, decrease in agricultural holdings and products, and consequent fall in the revenue to the State.

The question therefore arose as to how best this evil could be combated : the problem was not only to try and rehabilitate the deserted centres, but also to prevent as much as possible the loss to the State of the people migrating to other areas due to the frequent repetition of Famine conditions. Migrations for want of drinking water, specially in summer months, was a common feature and this required prompt attention.

Amongst the most acutely suffering areas, Raichur, which is not only the largest but at the same time third ranking cotton producer, was periodically visited by famine and drinking water scarcity. Tragic reports of the afflictions and distress which people suffered, particularly in this district, were pouring forth year after year, and resulted in the Government through the Revenue Department, carrying out a detailed investigation of the matter. The state of things with regard to drinking water was particularly most distressing due to the lowering of groundwater and consequent inability of the villagers to sink wells to great depths to meet the perennial

supply; in consequence, people had to go a long way to fetch water from some filthy pit or pond or even step-well which, being shallow, had collected rainwater, only to get dry in summer.

In order to prevent the migration of the people for the mere want of drinking water supply, and thus offset the indirect loss to the State, it was decided by the Government to provide perennial, pure and protected drinking water supply to the villagers, through the creation of the Well Sinking Department which was solely entrusted with this work.

Under the famine prevention measures and with funds from the Famine Reserve, the Well Sinking Department was inaugurated on April 1928 with the late Captain Leonard Munn, O.B.E., M.E., as Special Officer in charge of the Department. Captain Munn, prior to his enlistment in the Royal Engineers during the Great War of 1914, had, besides his other activities in the State, worked in the capacity of Mining Engineer. At his suggestion, the Government granted permission for his taking over charge of the 'Geological Survey Department' at the same time so that the two Departments could be mutually helpful. The question of tapping groundwater resources in wells is intimately associated with the knowledge of the geology of the country and when the problem is complex it can only be worked out by geologists with intimate knowledge of the area.

The activities of the department in this respect were first put to test in the Raichur district, with headquarters at Lingsugur (Lat: 16° 9′ 30″ Long: 76° 31′ 45″) which is 56 miles west of Raichur town a terminus of M.S.M. and G.I.P. Railways.

The average annual rainfall in parts of the State is estimated at thirty to thirty-two inches and because of its freakish distribution, even this much of the rainfall sometimes proves insufficient and inadequate as to result in bad harvest and scarcity, though not resulting in absolute famine conditions. But in areas where the average rainfall is less than twenty-five inches, the visitation of famine becomes a common feature resulting in inadequate drinking water supplies from the so-called village wells. These wells have not gone to sufficient depths to tap dependable groundwater resources, due to the poverty of the villagers and their inability to meet the huge cost of excavation to those depths to meet the groundwater. For a part of the year, the stagnant water in dirty ponds, pits or nalas forms their source of drinking water; during summer these temporary sources get dry and consequently they have to face the greatest hardships to procure even a potful of drink-

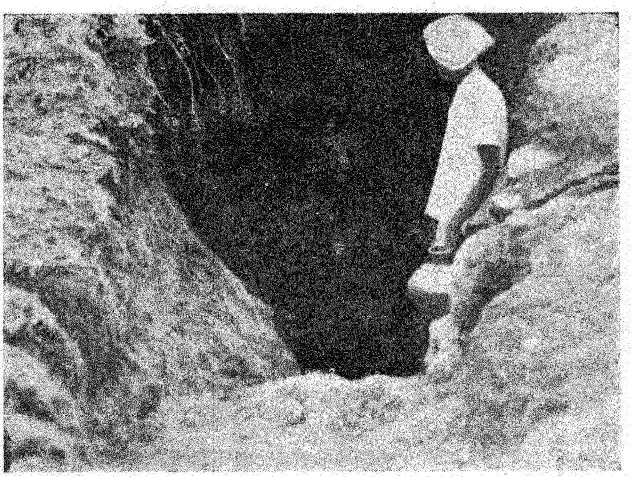


PHOTO PLATE. NO. 1.—*A mere pit situated amidst most insanitary surroundings, being the haunt of many water-borne diseases. The only source of water supply in most villages before the activities of the Well Sinking Department.*

ing water—the most *Primary* and *Vital* necessity to life.

The object of this Manual is to deal as briefly as possible with the conditions governing the distribution of underground water which in their turn depend largely on Geology, Physiography and Deforestation, etc., and also with the technique of well sinking giving details of the organisation which was set up in His Exalted Highness the Nizam's Dominions, to tackle this vital problem.

Part I of the Manual deals mainly with conditions in relation to geology and physiography and Part II with the ravages of the guinea-worm disease and the part played by the Well Sinking Department in combating this great danger. Parts III and IV deal with the technique of well sinking and the details of excavation, blasting, lining, tube wells, workshops, etc.

It may be mentioned that the methods adopted by the Well Sinking Department and its achievements are somewhat unique. Here perhaps for the first time in India, well sinking is taken up as a comprehensive and extensive problem affecting as it does the lives and well-being of thousands of human beings. Being a pioneer work the Department had to evolve their own technique and had valuable lessons to learn through their own mistakes. Hyderabad has undoubtedly given a lead and it is only to be hoped that other parts of India, particularly South India, where conditions are not dissimilar, will soon tackle the problem of providing protected water supply to those teeming millions whose lot has cast them into villages scattered over a barren countryside. The object in writing this Manual incorporating as it does the results of experience gained by the author during the last twenty years or more, will be amply served if it proves helpful to others engaged in similar work.

The author would like to take this opportunity to thank Dr. M. S. Krishnen, Ph. D., of the Geological Survey of India and Dr. C. Mahadevan, M.A., D.Sc., F.A.S., of the Andhra University, both eminent and discriminating geologists, who have spared much of their valuable time in going through the manuscript of the Manual. Their encouraging opinions have been a source of great inspiration to the author. The author must also acknowledge his gratefulness to Messrs. H. S. Krishnamoorthy, Geologist and S. K. Subba Rao, Assistant Engineer who helped indefatigably in the preparation of the Manual.

Hyderabad-Dn. D. V. RAO.

Chapter I.

GROUNDWATER SUPPLY.

Sources of groundwater

The main bulk of groundwater is derived from 'meteoric' sources, principally rainwater. There have very occasionally been cases where waters were surmised to have been derived from deep seated or 'Magmatic' sources. These do not normally influence in any way the underground water sources and are merely of academic interest. As groundwater derived from 'meteoric' sources almost exclusively accounts for all the water that supplies human requirements we are concerned in this Manual with 'meteoric' waters only.

General considerations.

The amount of rainfall is of primary importance in the formation of groundwater : besides the above, other equally important factors such as topography, nature of soil and sub-soil, the physical and structural features of the rocks have also to be taken cognizance of when tackling problems of groundwater resources. As these features go to modify the conditions of groundwater in an area individually as well as cumulatively, they are dealt with below in detail, adequate enough, to make the subject intelligible.

Generally speaking—other factors being normal—the greater the rainfall, the greater is the percolation of water underground, but the manner of the distribution of the rainfall has a very important bearing on the replenishing of groundwater resources. If the rainwater is distributed gradually over a long period, a greater amount of percolation results than when torrential rains fall over short periods, for the latter gets lost as runoff. Other factors affecting runoff and intake are thickness of the soil mantle, presence of vegetation, slope of the ground and climatic conditions. Reference will be made to these later.

The monsoons.

In the Hyderabad Dominions rainwater is derived principally from the south west monsoon which usually breaks during the second week of June. As is well known, the south west monsoon has its origin in the Indian Ocean and from a reference to the map, it is seen that

Hyderabad State is situated at a considerable distance from the coast line. In consequence, only a moiety of the clouds that fail to precipitate near the western coast supplies the rainfall to parts of the State. This accounts for the comparatively low figures of annual average rainfall in the State. To a minor extent, the north east monsoon also brings some rain especially to the eastern and central parts of the State. On account of the geographical situation of the State, it is not unusual to find freakish conditions and uncertainties with regard to the precipitation from both the above sources of rainwater and consequently both agricultural and groundwater resources pass through great vicissitudes and scarcity conditions.

Disposal of rain-water

The amount of rainfall is distributed in several ways; part of it is evaporated, a further part is lost as runoff and the remaining part percolates as intake into the ground to form groundwater.

Evaporation

The proportion of rainwater lost through evaporation depends upon the temperature, wind velocity nature and condition of the ground and the level of the zone of saturation of underground water; it is greatest on flat country and greater in hot weather than in cold; it varies with the seasons and with the humidity of the atmosphere.*

From a limited number of experiments carried out to determine relative evaporative properties of different surfaces, taking unity as evaporation factor for bare ground, the value for pasture land has been found to be 0.7, for cultivated land 0.8, for light forests 0.6, and for dense forests from 0.2 to 0.4. The importance of forests in controlling the evaporation is obvious from the above comparative figures.

Runoffs.

The actual runoff is equal to rainfall minus loss due to percolation, absorption and evaporation; these losses are difficult to estimate accurately either individually or collectively; they vary greatly in different regions, depending as they do upon physical features, geological formations and condition of ground and atmosphere.

"The runoff is greater in barren, rocky country than in fertile districts, where a large proportion of the rainfall is held up by the thickness of the vegetation or absorbed

*T. P. H. Veal—The Supply of Water. Chapman & Hall—1931.

by it. The effect of trees and plants is often well illustrated in the opening up of countries of ample rainfall. The clearing of forests and jungle naturally results in an increased runoff. Development begins at the coast and towns and villages spring up along the banks of the principal rivers, which form lines of communication before roads and railways are constructed. As development proceeds inland, the resultant clearing, levelling and substitution of impervious surfaces for those of a more permeable nature, divert to the rivers a large proportion of the rainwater that previously stagnated in hollows or was absorded by the trees and undergrowth. The earliest settlements are usually sited close to the river banks, often in the flood channel itself, so that the greater frequency of flooding which naturally follows development may render necessary the removal of villages and towns to higher ground."*

Percolation.

The percolation factor is determined by the nature of the strata underlying the surface soil and sub-soil. If they are of an impervious nature and are free from cracks and joints, the loss from percolation is negligible. On the other hand, if the rocks are permeable or broken up by cracks and faults, as much as 25 per cent. of the rain falling may pass into the underlying strata. Part of this groundwater may soak lower down and reach the zone of saturation.

Absorption.

The amount of rainfall absorbed by plants and soil, depends mainly upon the condition at the beginning of the storm, *i.e.*, whether they are wet or dry. Obviously absorption will be much greater at the outbreak of the monsoons when the surface is dry and thirsty, and the loss will be negligible through this source when the ground is either moist or so saturated with rainwater.

Intake.

In contrast to the factors of runoff and evaporation which result in the loss of the rainfall in relation to groundwater resources, both percolation and absorption help to conserve the rain to augment the groundwater ; thus intake has a direct bearing on the formation of groundwater and is controlled by conditions of the nature of the precipitation of the rain, the gradient of the ground and of the type of soil covered by the vegetation. The part played by vegetation, especially forests, is far more important and vital than is generally realised.

*T.P.H. Veal— The Supply of Water. Chapman & Hall— pages 33-34.

It is relevant to point out the disastrous results described above. In our own State, even within living memory, it is known that the deforestation in several areas has resulted in the diminution of the rainfall, lowering of the water table and erosion of soil.

Deforestation and resultant effects.

The Archæological evidences in the Raichur district go to show that this part of the country was once covered by a thick forest with a large number of tanks and plenitude of water. At the present time the conditions are the reverse—thanks to the ruthless deforestation that has gone on in that area. It is high time that the people and the authorities in the State become alive to the dangers of deforestation and that urgent steps are taken to reforest denuded areas and to stop completely the clearing of forests for agricultural purposes. Those having the welfare of the State at heart cannot but see with a pang the felling of trees in such areas where there are still a few forests. Apart from the national wealth perpetually afforded by well kept forests to the State, the indirect results of climatic changes that they bring about are themselves serious enough to engage our earnest thought and attention. Another indirect adverse result of deforestation and the consequent lowering of water table is the introduction of salinity in soil and sub-soil making in large areas even the major supplies of water unfit for consumption either by human beings or even by cattle. It is known that salinity, at least a great part of it, is brought by the absence of surface and sub-surface drainage such as would exist in areas with fairly good rainfall.

The quick runoff of rainwater through the deforestation and burning away of even shrubby jungles has accelerated soil erosion, resulting in large tracts of cultivable land being rendered useless for agriculture and other purposes. The State which is almost entirely dependent upon agriculture for its prosperity can hardly afford to look with equanimity at a situation forced through thoughtless denudation of forests and vegetation. It is estimated that each torrential rain results in carrying away of several hundreds of tons of soil from even small areas if the forests do not exist in the vicinity to retard the progress of the runoff.

Soil erosion, a serious problem

If the soil is unprotected by vegetation, strong tropical winds combined with storms often carry away good quantities of fine soil. Obstructions such as trees and forests in the path of even the strongest winds are known to result in the deposition of the particles of fine soil generally carried by

them. The urgent necessity of afforestation in the State must be apparent to any one who looks squarely at the problem confronting us.

In the paragraph under 'Runoff,' attention has been drawn to fact that deforestation often results in frequency and intensity of floods in nalas and rivers with serious loss to life, property and soil. F. Dixey, a great authority on Water Supply* remarks:—

> "In spite of the fact that a quarter of the rainfall might be withheld by the forest cover and re-evaporated without reaching the soil, the loss from the three quarters that did reach the soil was five times less (some authorities said six times) than from that which fell on unforested ground, the end result being that more water was retained by the forest covered soil and allowed to percolate to the deeper layers.
>
> "It has been stated on the highest authority that the forest litter, the moss-covered and leaf strewn ground, was capable of absorbing water at the rate of from 40,000,000 to 50,000,000 cubic feet per square mile in 10 minutes water whose progress was delayed by some 12 to 15 hours after the first effects of a heavy freshet had passed. Thus the upper spongy humus layer and the underlying unhardened porous mineral soil, penetrated and kept open by the deeper ramifications of the tree roots, could hold a large quantity of water before it became thoroughly saturated, and when this point was reached the flow-off to the springs and water channels was gradual and prolonged. This uniformity of flow was continued throughout dry periods, thus mitigating the evil effects of alternate floods and droughts."

The conditions of drought brought about in other countries have been carefully studied and from the published reports it has been found that one of the main causes was the ruthless destruction of forests. Summarising the results, Dixey remarks:

> "In 1920 the Government of the Union of South Africa appointed a commission to enquire into the best means of avoiding losses by drought, and in due course a valuable report of wide application was issued. An important finding of the Commission was that one of the main causes of drought condition is the destruction of vegetation, which leads to the erosion of the soil and thus to a diminishing

*F. Dixey—A Practical Handbook of Water Supply.

efficiency in the rainfall. Although a large part of South Africa was dry long before the white man arrived, enormous tracts of the country have since been wholly or partially denuded of their original vegetation, with the result that rivers and water holes described by early travellers have now dried up or disappeared. While the mean annual rainfall of the Union does not appear to have altered appreciably within recent historic times, its economic value has none the less been greatly impaired as a result of diminution in the absorptive properties of the soil : this diminution is ascribed to the destruction of vegetation in the course of farming, by over-grazing, and by bush fires as well as to the hardening of the soil by sun-baking and the trampling of cattle. Thus, while the quantity of rainfall received shows little variation, the amount absorbed by the soil is continually decreasing and this problem forms the most serious factor in the development of the great South African droughts."*

It therefore becomes very urgent that schemes for the afforestation of the deforested areas should be immediately taken up, and for every tree that is even now being felled another in its place should be planted so as to evolve a policy of maintaining and increasing the forest areas for the benefit of the State as a whole. Any further delay in this matter would result in disastrous effects and it may be too late to combat the evil caused by ignorance and neglect.

Some of the best methods of preventing soil erosion (which has been dealt in detail elsewhere) are, Field Bunding, Bush and Terrace growing and Trench digging on the limits of agricultural lands and by reforestation in non-agricultural hilly and highland catchment areas. The author has advocated in a special note a comprehensive scheme of babul plantation to meet the urgent demand for afforestation.

Soils and their influence on groundwater

The nature of soil covering the surface is an important factor in the conservation of groundwater. A coarse or fine soil such as mooram or black cotton soil can absorb a greater amount of water than a hard rocky ground. This absorption is controlled by the size of the soil particles and its porosity. Thus black cotton soil which is in a colloidal state of division can absorb about 52 per cent. of this water which is far greater than the quantity that could be held in a coarse or medium grained mooram soil. We must, however distin-

*F. Dixey—Practical Handbook of Watr Supply— p. 25.

guish between the property of absorption or retention of water and of *water yielding* capacity of soils. Porous mooram soil as well as sandy soil will yield proportionately much greater amount of water than black cotton soil. A soil blanket always helps in the conservation of the rainfall in an area and augments the sub-surface resources. The importance of preventing soil erosion for the conservation of rainfall can be well appreciated from this aspect also.

In tapping water from soils, it must be pointed out that the part that drains into the well is merely the gravity water or "*gravity groundwater*" and that which is not available in a well but is retained by the interstices of the soil known as "*soil* or *ground moisture*." These are expressed as specific yield and specific retention respectively and these two together equal the porosity of the rock. The water which is retentive in the soil can be drawn by the plants for their growth. From this it is seen that the mere absorption of rain water by soil does not necessarily imply the replenishing of sub-sruface water resources, A thick black soil mantle, for instance, is capable of absorbing and retaining a fairly large volume of water with a consequence that often in such areas, it is only the junction zone between the soil cap and the underlying rock that yields some water—which often dries up in summer —and excavation in the rock has often to go very deep to meet with dependable water table. In a loamy soil, as the medium is more porous, there are greater chances of the underlying rocks being augmented with water ; for this reason, sub-surface water is at comparatively shallow depths from the surface.

Rocks and their permeability.

The rain-water after percolating into the soil gravitates further down into the highly weathered or partially weathered or hard jointed rocks that underlie the soil mantle. The factors that control the flow of water undeground are gravity and molecular attraction. In rocks with large openings such as joints, cracks and fissures, gravity is a dominant factor which causes the water to percolate from the surface into deep zones and also laterally to long distances. When, however, joints and cracks are few and far between, the water is held in interstices of these rocks. The porosity of the rock is an important factor in determining the quantity that can be held and yielded in such compact formations. Here, molecular attraction and capillarity account a great deal for the '*water retaining*' and '*water yielding*' capacity besides the porosity of the rock.

Chapter II.

DISTRIBUTION OF UNDERGROUND WATER.

Saturation zone and water table.

Generally all rocks that are exposed at the surface are more or less weathered, forming permeable beds for the easy percolation of rainwater to form groundwater at varying depths according to the depths of decomposition and the depths to which the joints in the underlying rocks extend. It therefore becomes obvious that the depth of groundwater is not the same in every place, and particularly in cases of crystalline rocks having a network of fine cracks and joints, the distribution may not only be irregular, but may even be interrupted in places. Due to irregularities of rock surfaces it may happen that a projecting piece of almost compact rock may impound water on one side whereas on the other, the water may be free to seep into the sides of low lying valleys.

The upper surface of this groundwater is known as the water-table, and the depth of this water in the permeable rocks below is known as the *Zone of Saturation.*

Capillary fringe.

Usually, above this water-table, there is a fringe of moisture which may vary in thickness according to the nature of the interstices. This moisture zone is due to the molecular attraction—capillarity—induced in the fringe, where the water is kept suspended above the water-table to a height at which the two opposing forces, molecular attraction, and gravity, come into equilibrium. This capillary fringe will reach its maximum thickness in a fine grained loamy material, getting thinner in sand and almost disappearing in clean gravel.

In places where the groundwater is shallow, the capillary fringe may extend very near the surface to lose water by evaporation or by absorption by plants, which keep on a continuous movement of water from the water-table to the surface. This capillary fringe therefore fluctuates according to the fluctuations of the water-table.

The zone of aeration.

The zone of aeration, where the interstices are filled with atmospheric gases, is that part of solid material lying between the surface and the ground-

water table. The thickness of this zone is also variable and in cases mentioned in the above paragraph it may be altogether absent. This variation is again controlled by the physiographic and geologic conditions available in an area. In certain cases of perched water table, there may be one or more zones of aeration.

From the foregoing descriptions, it is clear that the zone of aeration is divisible into three belts as illustrated in the diagram below :—

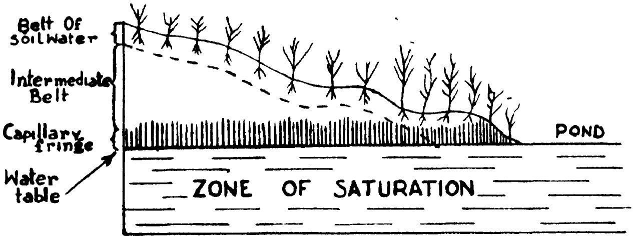


Fig. 1. *Relation between the three belts of the zone of aeration and the zone of saturation. (After O. E. Meinzer).*

Vegetation and water-table

When the groundwater is not at a considerable depth below the surface, certain kinds of plants which are capable of sending in their roots down to the limits of capillary fringe, absorb that water which is thus continuously kept replenished from the zone of saturation, and in this way great quantities of water may be discharged into the atmosphere by transpiration of those plants. In cases of small limited supplies of groundwater, this loss may greatly reduce the supply of water otherwise available in wells, but, in general, this is greatly offset by the increased percolation of water underground and by the reduction of evaporation due to vegetation and the leaf covered moss-grown ground combined with the shade cast by the trees on the ground. Some types of such trees that live on groundwater in the arid regions are some kinds of palms, cotton-wood, etc.

Forests and water-supply

Great controversies are going on still as to whether forests induce beneficial effects on the groundwater supplies in view of the two opposing factors of (*a*) loss by transpiration and (*b*) gain in 'intake' into the ground on account of interception of rain water, formation of greater permeable material caused by the disintegrating action of tree roots and prevention of eva-

poration ; the whole problem is so complicated that it has to be studied for the present in relation to particular localities, and therefore does not admit of regional consideration. From what have been said in the foregoing paragraphs, it may safely be concluded that forests exercise beneficial effects as regards water supply and stream flow, and, in order to bring these features, the hilly or mountainous portions of the catchment basins of the area should first be forested. Other contributory factors in the afforestation of an area are described under 'Deforestation and its resultant effects,' page 7.

Depth of water table

From the foregoing discussions on some factors which decide the depth of water-table it will be seen that it is governed primarily by topographic, geological and climatic conditions. Generally speaking, the water table changes with the changes in the surface of the country, except under some exceptional conditions. Usually the water table will show itself as springs on or near the surfaces of valley floors, and may lie more or less far below on ridges and hills.

Lower Limit of groundwater

No hard and fast rule can be arrived at as regards the lower limit of groundwater which is again dependent on so many factors. In crystalline rocks, where the groundwater is due to the presence of joints and cracks in them, it may be useless to go to greater depths of from 150 to 200 feet.

In areas of alluvial deposits composed of alternate layers of sand and shale extending to very great depths as, for instance, the Indo-Gangetic plains, the limit of groundwater may go far beyond 5,000 feet. Similarly, in sedimentary areas, porous rock such as sandstone which may lie at great depths may yield water if that bed has by some source or other received sufficient amount of water to saturate it. The lower limit of groundwater is therefore variable in each area according to the geological formation, topography and the amount of rain-fall, etc.

Fluctuations of the water-table

It is a common observation in wells which are sources of water supply, that water levels show appreciable changes of rise after rainfall and fall during summer months. This rise or fall is not sudden, for the water takes some time to pass through the soils and rocks before it could reach the groundwater limit. Generally, on low lying areas, these fluctuations are found to be greater due to very slow

movement of water than in highly inclined surfaces where, the flow being quicker, the water table rises but little.

In moderately deep wells of an average depth of 60 feet the increase in their yield is noticed from four to six months after the rainfall, and this period may be taken as the time taken by the rainwater to percolate downwards to reach the groundwater limit.

Besides seasonal changes, other factors such as atmospheric pressure affect the depth of water-table. A rise in atmospheric pressure will naturally tend to press down the water level in the well but locally raising the water-table elsewhere.

Wells which are situated in the neighbourhood of surface water supplies will show fluctuations in their water level according to the fluctuations in those surface waters.

Tidal waves also impose their effects on water levels in wells near shores affected by them and the wells will show high watermark several hours after high tide.

Excessive pumping may result in reducing the water level in a well, and excessive irrigation may raise the water level causing serious injury to agricultural lands.

The lowering of groundwater may be brought about by regional aerial desiccation which has already been dealt with in detail in the Introduction to this book.

Nature of underground water

The disposition of water underground sometimes presents very remarkable and baffling features that it is not often possible to lay down a general rule of thumb for large areas: all the same, a careful study of the rocks, the nature of topography, soil cover, etc., would reveal the existing local conditions to enable one to arrive at a satisfactory deduction of the nature of underground water which will hold good over limited areas. Underground water courses such as those claimed by water diviners do not always exist; nevertheless such free flows may occur in limestones which, owing to their ready solubility but impervious nature, admit the formation of caverns; percolation beneath the surface of dry river beds when the deposits are coarse enough to allow the water to pass freely through them give rise to subterranean streams. The lakes reported by well drillers are merely beds of saturated sand or any other porous strata. The water that is eventually tapped or encountered is merely that lying near the surface of saturation at the particular spot selected.

In some districts such as the enclosed desert basins the water is in the form of an underground lake and without movement. The volume depends upon the conditions of occurrence, the water often filling or partially filling strata of considerable thickness extending down fissures several hundred feet deep or saturating bodies of decomposed crystalline rocks.

In the case of granite and other crystalline rocks the underground problem presents peculiar conditions, which are difficult to study. Ordinarily such rocks are not underlaid by a porous stratum and are too compact to carry any water supply. Others are however broken by joint planes and occasionally disintegrated to great depths. Some of the crevices extend for long distances and in certain other localities pass under clays or other confining deposits in lower lands, so that '*head*' is established and they may yield an artesian flow.

It has often been remarked that the sheets or streams of underground water that exist may eventually find their way into the seas or oceans. Theoretically considered, such a phenomenon may be true in case these waters are considered to be in the form of streams similar to those at the surface or as continuous sheets enveloping the earth but even in such instances, other underground geological features (such as the presence of dykes, reefs, veins, faults, folds, etc.) so complicate and modify the situation that for all practical purposes such an idea may be dispensed with as non-existent. Even in places where the groundwater is in lateral motion it is so slow —perhaps from one quarter to one half mile the greatest within an year—that it may be considered as practically negligible. By this period of one year the subsequent monsoon would have not only set in, but completed when the groundwater would again be replenished, maintaining the store of that water. This slow lateral movement of underground water therefore accounts for some springs which begin to flow most abundantly during the dry seasons. The most common conception of the nature of groundwater which is available in wells is that they are usually disposed in more or less definite areas and that only in exceptional cases streams may exist as under nala or river beds.

Surface relief and groundwater conditions

The relief of the land has a very important bearing on groundwater conditions, that at some place and at some time or other on the surface the groundwater emerges as seeps and springs. There are many types of springs, classed as gravity, junction zone, artesian and deep seated, as well

as fault springs each of which is self-explanatory and needs no elaboration. In a low-lying flat country composed of porous formations the water nearly fills up the rock and this water may be available in wells sunk to shallow depths. In a hilly or mountainous region the water that percolates into the ground will very soon tend to seep laterally and begin to flow as springs at different levels. In areas of highly undulating surface with ridges and knobs here and there the percolated water would also gradually seep into minor and then eventually into the major valleys and emerge as springs at some favourable spots. Under these circumstances the movement of groundwater in the resultant direction (one due to gravity downwards and another laterally due to head or pressure within it) will be comparatively higher due to local declivities, sudden fall, etc., of the surface than that in a normal low-lying country.

It is therefore clear that except in places where gullies or valleys have been eroded down to a water-bearing stratum or where water emerges out of the ground in the form of springs, at all other places where these groundwaters can be tapped by means of wells the choice of sites becomes of paramount importance. Normally, springs even with large yields issue forth without much head from practically the ground level. If however, the reservoir of the water emerging out as spring is held under pressure it shoots forth to heights from a few feet to a few hundred feet above the ground level; such springs are called '*artesian springs.*'

Artesian water.

The term 'artesian' is derived from the old French Province of Artois where wells of this type were first encountered. Whenever water is confined under pressure either beneath impermeable strata as in cases of sedimentary rocks or beneath beds of clay overlying the gently inclined surface of a highly fissured crystalline rock, or waters drawn into the rock by gravity against the friction of narrow fissures, such water tends to rise to the surface when tapped by a well or borehole. The height and rate of flow depends upon the head or pressure of water.

Such artesian conditions may be encountered even in superficial deposits of alluvial and lacustrine origin, provided favourable underground and topographical conditions exist. Since alluvial deposits usually occur in the valleys of great water courses we could expect to meet with artesian flows in such regions. The great Indo-Gangetic plain may be mentioned as an illustration in this connection and from

recent experiments such artesian effects have been encountered even from very great depths in the area. These artesian wells derive their flow from beds of sand or gravel sandwiched between beds of clay.

The source of pressure on such alluvial deposits is mainly due to the weight of the groundwater table in the adjacent uplands which presses down upon the water confined within the water-bearing strata from which the flow is obtained.

Semi or sub-artesian effects are also encountered in some formations where the head and the flow are determined by hydrostatic and hydrodynamic considerations.

CHAPTER III

ROCK STRUCTURES AND WEATHERING

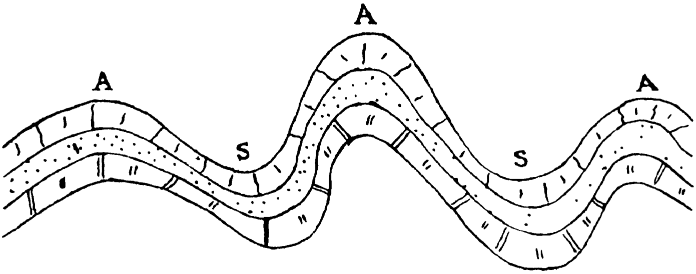
THEIR RELATION TO GROUNDWATER

In the previous chapters it was pointed out that certain rocks are porous and are capable of holding good supplies of water whereas others, though non-porous, are capable of holding water in their bedding planes, joints, crevices and fractures. Other structural features in rocks such as faults, folds and the unconformities, also gneissic and schistose planes control the distribution of groundwater.

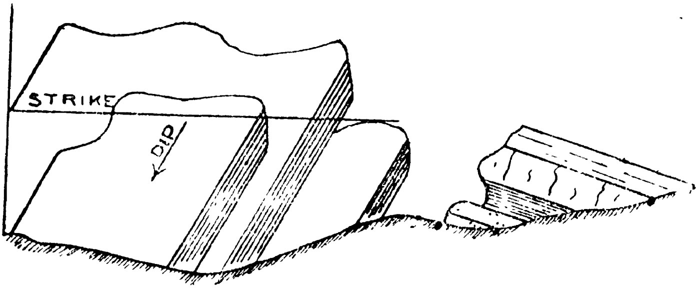
The sedimentary rocks, *i.e.*, rocks formed by the settling down of suspended as well as chemically precipitated materials on the bottoms of oceans, seas, lakes or rivers are first laid down in an almost horizontal form. Subsequently, due to enormous earth forces, these horizontal rocks are thrown into inclined positions and folds, resulting in troughs and arches and sometimes broken (faulted) and displaced strata ; the water which once covered these beds having receded the rocks are exposed to the surface, giving rise to new land masses. These features greatly influence the water-bearing capacity of these rocks. Some of the commonest rock features that may be encountered are given below :—

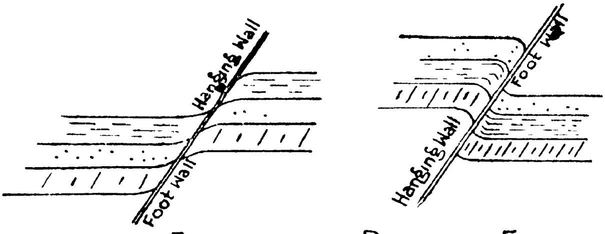
1. Anticline is the arched or dome-like fold in a rock.
2. Syncline is the trough-like fold in a rock.
3. Dip is the angle which a bed deviates from the horizontal and is expressed either as a gradient or in degrees.
4. Strike is the trend of run of a rock or the intersection of an inclined bed with the horizontal surface and is therefore at right angles to the dip. The direction of the strike is expressed in the following manner N 50 E, N 50 W, etc.
5. Fault is a feature in a rock which has displaced it relatively to another. There are various divisions in a fault such as normal, reversed, trough and step faults.

Each of the above features in a sedimentary rock greatly affects the distribution of groundwater.



A: Anticlines. S: Synclines.





Normal Fault Reverse Fault.

To exemplify, in a folded stratum, it is usual to find water collecting in the troughs of the folds. (In other instances where this bed yields oil, it is found to collect on the anticlines due to its low density and volatility).

Dip or inclination of strata influences the water by carrying it along its plane to lower levels where under favourable conditions they may get stored.

Faults being zones of weakness often with porous and compact rocks in juxtaposition may serve as planes yielding water.

Igneous rocks

Coming to the ingenous rocks, *i.e.*, those formed from the molten rock or '*magma*' deep within the earth's crust, which are now uncovered by the erosion, the permeability of water to lower depths is determined by the presence of joints, fissures, pores, cleavages, etc. The joints are the results of shrinkage due to cooling of a rock as well as weathering whereas fracture is the result of pressure in a rock mass produced by bending, folding, etc. Usually there occur two to three sets of more or less defined joints intersecting one another. Joints are more pronounced and of much wider void nearer the surface than in the deeper zones and weathering often proceeds along the joint planes. The weathering through these joints goes on to such an extent as to leave these weathered boulders perched alone or one on the top of the other in '*Tors or Kopjes.*' Between Lingampalli and Hyderabad on the N.S. Railway, a traveller is attracted by this very picturesque and special type of weathering.

Metamorphic rocks.

Cleavage and divisional planes are characteristic of metamorhic rocks such as schists and gneisses; these are produced by pressure and sometimes by rearrangement of minerals along some definite planes. The weathering of these rocks results in sets of other planes or joints.

In contrast to joints which are often superficial, gneissic and schistose planes extend down to great depths. The influence of this factor on sub-surface water is a feature to reckon with in the choice of well sites.

CHAPTER IV

THE QUALITY OF WATER

From whatever source the water is derived, either meteoric (superficial) or magmatic (deep seated), it will never be found to be free from solid and gaseous matters in solution. It dces not follow therefore that such waters are unfit for drinking purposes.

In fact, the pure water which is obtained by distillation (*i.e.*, distilled water) is tasteless and is never preferred for drinking. Water that contains a certain amount of dissolved gases or solids imparts a taste that is often relished. The amount of dissolved material should however never exceed a certain limit as otherwise it will become again unpalatable to the taste and injurious to health.

During the course of rainfall, the water that reaches the ground would more or less absorb gases such as carbon-dioxide (CO_2) and Oxygen (O_2) etc., from the atmosphere; in the course of its surface flow and downward percolation, it would further absorb other gases or take into solution mineral and organic matters derived from the soils or weathered rocks with which it comes into contact. During the first freshet, the surface waters may contain in addition a great percentage of bacteria, dust or other organic impurities. It is on account of this that epidemics such as cholera, typhoid, etc., often become rampant after the first rain. If the groundwater source is properly protected, these disastrous epidemics may be altogether avoided. It is a common observation that villages situated on nala or river banks and dependant on these sources for their water supply are almost invariably visited by cholera and typhoid after the first rains whereas villages which depend on protected water supply, such as draw-wells, are entirely free from such epidemics. This feature has been most amply proved in the districts of Raichur and Gulbarga and in consequence, the Government now afford protected water supply in the shape of wells to villages situated on perennial nala or river banks. The quality of the ground water in relation to its dissolved impurity would be mainly governed by the type and composition of the rocks

and soils and the period during which the water was in contact during its downward course with the rock or soil.

Though rainwater takes into solution salts from soil and weathered rocks during its percolation, it is an interesting fact that normally, the salinity in the water in rainy season and soon after is much less than that in the summer months. This is due to the fact that the volume of water during this period being quite large, salts are in great dilution. As summer advances and the sub-surface water resources get gradually depleted due to draw and desiccation, the salts become more and more concentrated, imparting taste to the water.

The following table summarises the information regarding the amounts of dissolved mineral matters in water derived from different geological formations in the Hyderabad State.

A statement of analyses showing the quality of water of some of the wells in the various Geological Formations of the State.

The quantities expressed are in parts per 100,000

Serial No.	Location	Geo formations	Total suspended matter	Organic and volatile matter	Total solids	Hardness		Calcium		Magnesium			Sodium			Silica
						Temporary	Permanent	$CaCO_3$	$CaSO_4$	$MgCO_3$	$MgCl_2$	$MgSO_4$	Na_2SO_4	$NaNO_3$	KNO_3	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Kazipet Ry. Stn. No. 1 Old well	Archaean Gneisses.	Very slight	0.06	48.5	27.5	11.9	20.0	6.3	9.0	5.4	..	..	..	..	7.0
2	Kazipet Ry. Stn. New well.	do ..	do ..	0.02	51.0	33.0	20.0	8.5	9.0	22.0	6.3	..	..	..	..	5.3
3	Dornakal Ry. Stn. Old well.	do ..	do ..	0.04	50.0	25.6	18.2	17.1	5.4	15.4	8.1	..	..	..	..	3.5
4	Dornakal Ry. Stn. New well.	do ..	do ..	0.07	44.3	27.8	7.7	15.7	4.9	13.4	7.5	..	..	..	..	2.5
5	Mahbubabad Ry. Stn. well	do .	do	0.09	90.0	33.0	61.0	25.7	11.0	15.7	31.0	..	..	..	..	5.2
6	Chintalapally Ry Station well.	Archaeon Gneisses.	do	0.06	32.1	21.2	7.3	15.8	Traces	9.0	..	3.4	..	..	..	4.8
7	Potkapalli Ry. Stn. .	do ..	do .	0.03	43.0	22.0	3.8	11.7	1.5	17.4		3.5	..	..	..	7.1

8	Nizamabad river well .	do .	do ..	0.05	30.0	24.5	1.7	13.0	2.1	8.1	..	..	..	..	4.7	2.0
9	Ramgundam Ry. Stn	Lower Vindhyans	Traces .	0.04	38.0	24.4	22.0	18.7	0.8	13.7	.	2.1	..	..	..	1.7
10	Singareni Collieries ..	Gondwanas	do	1.14	49.5	13.4	12.4	13.4	0.2	..	14.63	..	3.53	..	15.81	..
11	Tandur Collieries	do ..	0.25	..	182.1	31.0	35.2	28.3	..	2.3	42.03	..	15.52	..	81.00	..
12	Kohir Ry. Station ..	Deccan Traps	Very slight	0.04	60.0	28.0	10.5	20.0	8.0	17.3	..	7.5	..	..	.	2.0
13	Metalkunta Ry. Stn. ..	do	do	0.04	106.0	27.0	39.0	12.0	27.3	19.4	..	14.5	..	..	26.0	4.3
14	Manmad R. S. well No. 2.	do .	do ..	0.03	32.7	24.1	1.9	11.0	2.7	9.3	..	..	..	.	6.1	2.5
15	Do well No. 4	do .	do ..	0.03	35.3	26.0	1.9	12.1	2.7	9.8	..	.	..	..	7.0	3.0
16	Purna R.S. Glenfield .	do ..	do	0.03	35.7	26.1	7.1	12.3	4.2	9.8	..	..	..	..	6.1	3.0
17	Purna R.S. River well	do ..	do ..	0.09	50.0	25.5	2.6	13.7	3.4	8.3	..	..	5.7	6.0	6.1	5.7

We shall briefly review here the nature of salts present in groundwater in relation to their potability.

Hardness. Hardness may be defined as that property which causes water to decompose soap with the formation of insoluble compounds. It is usually expressed in degrees of hardness or in terms of calcium carbonate as part per 100,000 or grains per gallon. The hardness due to one grain of calcium carbonate per gallon is termed one degree of hardness. Temporary hardness is due to the carbonates and bi-carbonates of calcium and magnesium. Permanent hardness is due to sulphates and chlorides of the same elements. Temporary hardness disappears after boiling of the water whereas such a treatment does not affect the character of water in the case of permanent hardness.

The permissible amount of hardness in drinking water ranges from 8 to 17 degrees. Waters which are too soft or too hard are known to be injurious to health besides corroding away metallic vessels, lead pipes, etc.

Salinity. Chlorine in the form of common salt (NaCl) is present in varying amounts in all raw water. Excess of it however, usually indicates sewage contamination. In the arid districts such as Gulbarga and Raichur, there is present in the groundwater a greater amount of sodium chloride than in the wetter parts of the State. Sometimes, sulphates of sodium, calcium and magnesium are also present which impart a brackish taste to the water. According to Keller, the common salt affects water for drinking purposes as follows :—

(*a*) Water with 40 parts per 100,000 of common salt is without taste of salt.

(*b*) Water with 50 parts per 100,000 has a brackish taste.

(*c*) Water with 100-250 parts per 100,000 tastes strongly of salt, but is still bearable.

(*d*) Water with 250-500 parts per 100,000 is unbearable for continuous use.

(*e*) Water with more than 500 parts per 100,000 cannot be used as drinking water, but is still endurable by many plants such as Lucerne.

(*f*) Up to 300 parts dissolved salts per 100,000 is considered safe for working horses, dairy cattle and pigs.

(*g*) 300 to 1,000 parts per 100,000 is safe for sheep and grazing cattle provided concentrations of 700 parts and over are used for emergencies only.

(*h*) The extreme limit of salts for irrigation is taken to be 70 parts per 100,000 but plants will not tolerate more than 10 to 12 parts per 100,000 of black alkali (alkaline carbonates and bi-carbonates).

"The physiological effect of the dissolved solids very largely depends on their nature. Calcium carbonate has no harmful effect; alkaline carbonates are most injurious, alkaline sulphates least injurious, and alkaline chlorides, including common salt, are intermediate in effect. The immediate consequence of drinking water too high in mineral content is usually diarrhoea, but people gradually acquire immunity from this. Common salt betrays itself by its mawkish taste, and 70 parts per 100,000 renders water distinctly brackish. In the case of water mineralised by sulphate of magnesia (Epsom salts) a bitter taste is apparent but the only danger to be apprehended from this substance is due to its purgative properties."*

Organic impurities.

The organic impurities which may be present in water are of two kinds, *viz.*, animal and vegetable; the vegetable impurities resulting from the actual growth of large or small forms of vegetation in water are not dangerous in themselves but they form food for toxic bacteria and should therefore be kept down as much as possible.

Animal impurities, on the other hand, are highly dangerous and therefore every precaution is necessary to minimise their effects. It is for this reason that the Well Sinking Department insists on the removal of dung heaps and village filth from the vicinity of sites selected for excavation of wells.

"Polluted water may carry the germs of typhoid, dysentery, cholera, diarrhoea, hookworm infection, and other diseases in the case of human beings, or of hog cholera, foot-and-mouth disease, anthrax, and other diseases in the case of stock.

"It must be realised that the danger of pollution is ever present in water, no matter from what source it may be obtained although it is less likely to occur in deep seated bore-hole supplies than in surface or shallow well waters

*F. Dixey "A Practical Handbook of Water Supply", pp. 253-254.

The latter must always be considered as potentially very dangerous. Water stored in tanks and reservoirs frequently suffers contamination due to the presence of dead animals and insects as well as the droppings of birds and other creatures.

" Water in which any pronounced odour or taste is noticeable must always be suspected. Good potable water should be clear, odourless and neither too acid nor too alkaline, nor brackish but the presence of these characteristics should never be deemed proof of purity, for a sample of water may possess them all and yet contain enough disease germs to make it highly dangerous. In all cases of doubt, therefore, bacteriological and chemical analyses should be obtained, and for this purpose at least half a gallon of water should be collected in clean stoppered glass bottles.

" That disease has never occurred after drinking water obtained from any particular source is not necessarily a proof that the source is unpolluted. It is possible that the individuals concerned have acquired a high degree of immunity, and that this has prevented an outbreak from taking place but should a breakdown of immunity occur leading to the infection of any one person the contagion may spread rapidly."*

In the Well Sinking Department, for all practical purposes, the following features of the well water are determined before they are passed as fit for human consumption.

(1) Free ammonia which is indicative of the presence of organic contamination.

(2) Nitrites and nitrates both of which together indicate organic contamination ; if only nitrates are present, it may be due to mineral matter only.

(3) Chlorine expressed in terms of sodium chloride which determines the salinity of the water.

(4) Hardness indicating the presence of carbonates, sulphates of calcium, magnesium and sodium.

The Burroughs and Wellcome Company have put in the market a very efficient portable water analyses set which is being used by this department for finding out constituents as above mentioned. Items 1 and 2 give indications of water pollution from decomposed vegetable or animal matter near to

*F. Dixey—" A Practical Handbook of Water Supply," pp. 247-248.

the source of supply of that water, and items 3 and 4 about the quality of water in general though item 3 in certain exceptional and unlikely places gives a clue to the contamination of that water through sewage and of urine of man and animals.

The pollution of water is another great problem in the choice of well sites to get at pure drinking water supplies. The insanitary habits of the people, the dirty conditions of the villages and their precincts have by herding cattle, storing manure, etc., so fouled the ground for centuries that any hope of obtaining pure water within the village has to be abandoned and places selected far beyond the influence of such pollution outside the village limits.

When waters are found to indicate the presence of Ammonia or Nitrites or Nitrates, they have further to be bacteriologically examined to make sure of the presence or absence of bacteria, which, when taken into the system with the water, produce water-borne diseases such as typhoid, cholera, dysentery etc.

Purification of water

Waters can be purified of their suspended matter by a process of decantation (sedimentation), the time taken depending upon the size of the suspended particles. Other methods of purifying water are filtration, sterilisation, distillation, boiling, aeration etc., each of which, being clear to everyone, needs no further amplification.

Chapter V

WATER FINDING METHODS

Geology and physiography

In an arid country like Hyderabad, the problem of locating dependable water in wells presents very great complexities on account of the meagre rainfall ; generalisations based on incomplete data have often resulted in disappointment. It is quite easy in certain areas with heavy rainfall and favourable topographical conditions to locate a well site almost anywhere. Experience has proved that in the arid place of the Deccan even very slight factors normally considered negligible affect underground conditions favourably or otherwise. The two main factors involved in the determination of underground water resources are geology and physiography. The geological conditions tell us about the nature of the rocks, system of jointing or bedding planes, their inclination or dip and presence of folia, the depth of decomposition and their consequence of occurrence. Under physiography are included the topographic features such as proximity to hills or mountains, undulations of the surface, direction of the valleys and water courses, presence of vegetation and forests, etc., as well as climatic factors such as rainfall, humidity and prevailing winds. A complete appreciation of all these features individually and collectively is of paramount importance in selecting well sites.

Water divining methods

There has been a strange tendency even in educated minds to resort sometimes to occult sciences in the investigation of water finding. Water divining dates back to very ancient times and has been a matter of endless controversy. The divining rod is usually a forked twig with the two arms each 10 to 14 inches in length and about a quarter of an inch in thickness, while the butt is a few inches long. Usually hazel twig is often employed, but in places where this is not available, any other twig—but freshly cut of tough and springy nature—is also used. The two forked ends are held firmly within the palms of the hand, the palm with the butt end upwards. The diviner then walks over the area with the twig in position and it is alleged that when he passes over an underground stream of water,

the butt of the twig swings downwards due to a certain attraction which is rather unexplainable. It is said that in cases where there are huge stores of underground water the influence is so great as to cause the twig to break.

Some diviners use, instead, a piece of wire, a watch spring and so many other diverse objects. Scientists and phychologists have investigated carefully the art of water divining. Professor Gregory, a noted geologist, summarises their findings regarding this method as follows :—

(1) Those based upon fraud and practical jokes.

(2) Those due to unconscious imposture as with people who believe they are endowed with some special gift wherein they are superior to their fellows and the claim for the power of water divining is often associated with personal egoism.

(3) After these categories are separated there remains so large a residue for which some other explanation is necessary that the conclusion is adopted by some writers that there must be some actual force which directly or indirectly causes the movement of the rod.

The movement of the diviner is explained in two ways

(1) due to a kind of second sight.

(2) unconscious or subconscious movement of some occult forces.

In conclusion, it may be stated that the reasons for some of the successful diviners may be traced to their quick observation and an intimate knowledge regarding clues of the presence of underground water in the country within which they rigorously keep in, and beyond which they may prove failures. Hence, under such circumstances, an expert diviner may be of great assistance in the search for wate rbut there is no reason to suppose that he would secure higher proportions of successes than would an experienced geologist. In fact the successes of some diviners are due to the fact that the water table is wide-spread and that in the kind of country where diviners are most successful, water occurs everywhere.

Water finding machines.

Two water divining machines are on the market, but one known as 'Schmidt water finder' has been much used by this department during the early stages. The machine consists of a number of insulated windings of annealed iron wire, forming into a coil, which is placed vertically in a box in the centre of which

a feebly magnetised needle is placed in a horizontal plane. The whole box is so nicely finished that it can be carried easily from place to place.

When the machine is to be used, it is set on a tripod with the vertical coil of the wire coinciding with the plane of magnetic meridian and the oscillations of the needle noted. The higher the oscillation, the greater is said to be the quantity of underground water available at the spot. The makers claim that in the underground streams or bodies of water the earth's magnetic currents are so intensified as to be detectable by the instrument. So far no such currents are known to exist and the instrument cannot therefore operate on this basis as claimed by the makers. Besides the above features, the makers specify the rigorous observance of some conditions for the successful operation of the machine. These are :

(1) The machine should be tried between 8 to 12 in the morning and 2 to 5 in the afternoon when the greatest activity of the vertical earth's air currents are presented.

(2) It must be tried on a calm, dry, clear day and in a country as open as possible, as, an overcast sky, air saturated with moisture and wet surface of the ground influence the indications adversely.

(3) Experiments should be conducted in directions, S.E. and N.E.

(4) The machine should be protected from the direct rays of the sun as, when the coil gets heated, it may affect the oscillations of the needle.

(5) The machine should not be tried in forests or in close proximity to buildings or iron structures.

Such conditions are not easily obtainable in nature between the hours specified and even after going to the extent of waiting for such conditions, it has been found unfortunately that the trials have proved unsuccessful. Many tests were carried out with the machine and in most cases the results proved to be failures, and the experience of this department with the water finder has been of no advantage. The machine gave no oscillations of water when tested over a known spring yielding over 2,000 gallons per hour, but gave the gratest oscillation to the N.E. of a well which was dry, and sinking and tunnelling in the direction proved useless. Du Toit gives instances where bores gave 75,000 gallons and 14,000 gallons per day on lands where the machine gave no response.

OTHER INDICATIONS OF GROUNDWATER

Ground mists

Ground mists or fogs give indications of the presence of groundwater near the surface under certain conditions. They sometimes indicate the line of a sub-surface flow in certain porous beds.

Moist ground and seepages.

Damp patches on the ground or moisture horizons that persist far into the dry season are also indicators of groundwater conditions. They correspond very nearly to springs and seepages and after carefully examining the area and understanding the nature, occurrence and the direction from which such features result, successful well sites may be chosen in the direction of the seepage away from the damp or moist spot. Efflorescent patches on the ground give indications of the presence of groundwater.

Coastal areas

In coastal areas such as parts of Madras and other such cities, shallow wells near the shore yield fresh water. This water derived from parts of the rainfall in the area percolates gradually downwards but is prevented from seeping laterally into the sea by the sea-water—being denser than fresh water—and the relatively saturated beds of the sea-floor. A well, therefore, sunk near the shore yields sweet water derived from the coastal areas. Even at the surface the mingling of fresh water and salt water takes a very long time and evidences are still noticed amongst the mouths of the rivers or big deltas where the fresh water is found to flow over the denser sea-water for long distances without any appreciable intermingling.

Groundwater at high levels and on hills

It is normal to expect to tap groundwater by shallow wells in low-lying plains rather than at higher altitudes, but some exceptions to this rule occur where pockets of underground water may exist due to the presence of some porous or highly weathered portions of rock below, having collected the percolated rain water which cannot seep down the hill sides due to the surrounding compact rock. The perched water tables in some hill forts are probably of this origin.

River valleys.

The alluvial deposits if composed of sand and gravel, and situated by the side of a perennial stream, would yield good supplies of water. But if the deposit is broken up by finer beds of shale, the yield of water would be meagre. At the confluence of valleys

copious supplies of sub-surface water are frequently met with.

Old courses of streams and rivers sometimes afford promising areas of sub-surface water on account of the porous beds they contain and the favourable situation of drainage.

In steep valleys the accumulation of alluvium and the percolation of water underground being somewhat poorer than in broad open valleys with easy gradient, the yield of groundwater is generally not very copious. Sharp bends of river courses may be taken advantage of for the search of water, as both the overflow and the sub-surface flow will retard here, allowing water to percolate and saturate the subsurface strata. It is a common observation that in the dry nalas where villagers excavate '*cheshma*' or springs for water supply, the site is very often the bend of a stream. Even in selection of well sites on the bank such areas afford larger yield.

Rock talus.

Usually at the foot of steep hillsides or escarpments, a good amount of talus or rock debris is accumulated to great thickness which may contain supplies of water. A coarse deposit may yield water only for a short time since it is drained of its water sooner than a finer deposit such as alluvial fans formed by streams under hill slopes—which may hold water for longer periods and yield them only gradually to form a perennial supply. The seepage of water and the green patches of vegetation at the foot of these hill slopes usually give indications for positions of well sites to tap these waters.

If the detrital matters are of fine nature and yield water only very slowly then the supply may be augmented by constructing infiltration galleries.

In this connection the water supply of Aurangabad probably laid out by Persian Engineers in the days of Malik Amber in the early part of the 17th century may be mentioned.

*"The gradual rise of water-table as it approaches the base of a hill or a plateau is quite evident and it is this principle which the Persian Engineers took advantage of. Long infiltration galleries resembling horizontal wells were dug in the accumulation of talus and soil, lying at the foot of the scarps of Deccan Trap which surrounds the Aurangabad town. The water collected in these galleries were led by

*"Journal, Hyderabad Geological Survey Department" Vol. II, Part 2, page 157.

underground tunnels, most cleverly excavated by tunnelling in each direction from the bottom of small wells, carefully sunk at intervals, to an exact level, in the direction of the town. On the way to the town the gallery runs for some distance parallel with the Harsul nullah, and received more percolation from that source. The gradient of the tunnel is very slight. One main supply, out of fourteen is still fortunately functioning.............. The water emerges at the Gai Mukh, where it runs into a cistern. From that point the water is piped into the town in crude earthenware pipes set in lime concrete. The Engineers here showed great skill and ingenuity. Obviously realising that their pipe line would not stand the total pressure if the water was carried down at one stretch to the total fall of the ground to the town, the Engineers arranged that the water should be brought up by means of towers to its head and then allowed to discharge down a parallel downflow pipe, built into the tower, which connects with the next length of main. Thus any section of the pipeline could be repaired by blocking the rising main and at each of these towers distribution could be arranged as described below. When the town was reached, this same principle of water towers was employed for distribution. The Central vertical pipe in the tower was the rising main for one of its branches. Built into the tower around the rising main were as many pipes as were required for supplying mosques, cisterns or private places, at that point. The top of the central rising main was closed with a brass pot, the bottom of which had been removed and around the periphery of the brass pot were cut slits proportionate in size to the requirements of each distribution unit. These several slits discharged their water into the downflow pipes built into the tower leading to the various cisterns, etc. The principle was as simple as it was ideal and well worthy of study, for ....no such adequate town water supply system had been contemplated in the leading towns of Europe at that period."

With the modern products of earthenware and cement drain pipes the above principle can be much more simplified by either syphoning or cutting a trench and allowing the water to discharge.

Similarly percolation galleries along banks of streams or rivers will often give good supplies of water, and Tourneaure in his "Cyclopedia for Civil Engineers" Vol. VII, quotes cases where 30,000 to 1,000,000 gallons per day have been obtained by this means.

PLANTS AS INDICATORS OF GROUNDWATER

The evidences offered by a study of topography and geology of an area in relation to groundwater resources may be supplemented by the presence of certain species of plants in the locality. In humid areas, no conspicuous distinction in the growth or grouping of plants is clearly discernible owing to the abundance of groundwater, but in arid regions where the distribution of groundwater is irregular and meagre sharp distinctions in the growth and arrangement of plants are so marked as to conform in several cases to the general trend and nature of the groundwater.

In the study of the ecology of plants, it has been observed that wonderful and various indeed are the adaptations in nature to overcome adverse environmental conditions. In the arid seasons, several of the plants shed off their leaves and manage to keep themselves alive with the minimum amount of water. Sometimes, we see certain types of plants with green leaves even during arid seasons disposed along well defined trends. These are often indicators of water courses in the area.

A great deal of work has been done in countries like Australia, South Africa and United States to study the effect of underground water and vegetation and several publications deal with the results of such studies. In our own country, rural wisdom often takes the course to such indications. It is very interesting to note that a writer* of the 6th century A.D., had also described the disposition and quantity of available groundwater in relation to Indian plants. It would be a fruitful source of study to test to what extent his conclusions are borne out by facts.

The importance of vegetation as indicator of groundwater should always be borne in mind in the selection of well sites.

GEOPHYSICAL METHODS

Geophysical methods in the problem of studying underground structures such as folds, faults, dives, unconformities and others on the nature of distribution of sub-surface water have come into vogue during the last 50 years. Large strides have been made in this branch of study by the combined efforts of the Physicist and the Geologist ; as the name implies, some of the fundamental and very simple

*"Jalargalam" by Viraha Mihira.

principles of physics are employed in these methods in trying to unravel geological structures. The main types of geological methods are classed under the following groups:

(*a*) Gravity—Tortion balance.

(*b*) Magnetic methods—Dip needle.

(*c*) Electrical methods—Potentiometers and ratiometres.

(*d*) Seismic methods—Seismograph.

The gravity method with torsion balances is utilised mainly ... underground structures such as anticlines, syn-

...etic method is employed for prospecting for ...d other paramagnetic ores.

The electrical methods are very popular in the study of underground geology, such as presence of quartz reefs, dykes, water-table etc.

The seismic method helps to locate deep-seated structures in the crustal zones. It must be pointed out that in all these methods certain results are obtained which have to be interpreted most carefully, and considerable practice of experimenting and deduction in limited areas is necessary before any results could be claimed to be reliable. In prospecting for water, the electrical conductivity method with ratiometers has been successfully used in several countries. Saline water being a greater conductor of electricity than normal water, this method helps in locating even saline zones. Though geophysical methods of prospecting for minerals and water have come into vogue extensively in America, Africa, Australia and Europe, it has to be admitted that very little progress has been made in the use of these methods in this country. To be successful in the application of geophysical methods for interpreting geological structures, one must be a thorough field geologist with the complete grasp of the fundamentals of physics on which the methods are based.

CHAPTER VI

ROCKS: THEIR ORIGIN, OCCURRENCE AND CLASSIFICATION

As well sinking involves the excavation of both loose and hard materials the latter consisting of rock [illegible]dimen-tary, igneous and metamorphic origin, it is es[illegible] line the nature of these rocks, their origin, an[illegible]

The geological formations occurring in this [illegible] classified as follows:

Group	Formation	Age
ARYAN GROUP	1. Alluvium	Recent
	2. Older alluvials of Godavari, Tunga-bhadra, Kistna and Bhima rivers.	Pleistocene.
	3. Deccan Traps	Eocene, Oligocene.
	4. Gondwanas	Ranging from Jurassic to Carboniferous.
PURANA GROUP	5. Vindhyans 6. Cuddapahs	Pre-Cambrian.
VEDIC GROUP	7. Peninsular Gneisses 8. Dharwars	Archæans.

Alluvium and Older Alluvials

These occur in small areas fringing the rivers Godavari, Kistna, Tungabhadra, and Bhima, etc., and are only of local interest.

The '*Deccan Traps*' are effusive molten lava of igneous origin and cover more than one-third the area of the State, that is about 32,000 square miles comprising the districts of Aurangabad, Parbhani, Nanded, Bhir, Osmanabad, Bidar, parts of Gulbarga, Asifabad, Mahboobnagar and Atraf-i-Balda.

The *'Gondwanas'* composed of sedimentary shales, sandstones and conglomerates with beds of coal in the Barakar series occupy the eastern portion of the State comprising parts of Asifabad, Karimnagar and Warangal districts.

The *'Vindhyans'* composed of sedimentary limestones, sandstones, shales and conglomerates, occupy comparatively smaller areas of Gulbarga district underlying the Deccan Traps. Small patches of this formation also occur in parts of Asifabad, Mahboobnagar, Nalgonda, Raichur and Warangal districts underlain by the next succeeding groups of rocks known as Cuddapahs.

The sedimentary *Cuddapahs* are composed of quartzites, slates, limestones and conglomerates, and extend in a north-westerly direction to the Maner river in Warangal district and in Mahboobnagar, Nalgonda, Asifabad and Karimnagar districts.

The *Peninsular Gneisses* occupy the bulk of the other portions of the State with patches within it of the *Dharwars*, the whole together forming the archæan group of rocks. The archæans are composed of different types from schists, slates, gneisses and granites with intrusive dykes and quartz veins.

The Dharwars and the Peninsular Gneisses together form the archæan rocks, a portion of the former together with the latter being the result of igneous activity deep within the bowels of the earth. Subsequent denudation and erosion of the superincumbent masses have now exposed them to the surface. The schists, the granitic bosses, domes and hills, the narrow dykes (trap dykes) and the extensive horizontal spreads of basalts are some of the typical surface expressions of such igneous activity. By virtue of their mode of occurrence and formation, they present different structures and textures ranging from compact to fissile, coarse to fine grained ; these are very important in influencing the underlying water resources.

WELLS IN GRANITES AND GNEISSES

The term *'gneisses'* denotes a sort of banded metamorphic rocks, derived from rocks of igneous or sedimentary origin. Technically speaking, there are no true granites at the surface for all of them that are outcropping or are still buried under the surface have undergone some kind of change due to natural process of heat, pressure

and recrystallisation. The term '*metamorphism*' which usually means a change of form, is intended to embrace such rocks as gneisses, schists or slates which have all been altered or metamorphosed by dynamic or local agencies.

Underground water in gneisses.

The granites and gneisses which are hard and compact and range in texture from coarse to medium grained are usually traversed by two sets of vertical joints, one the major and the other the minor. These joints grow so fine at depth as to form but only capillary openings. Besides these as already mentioned, there are the horizontal cleavage planes at irregular intervals which, acting as divisional planes split the rocks into fragments of different forms and sizes. It is through such joints that rain water permeates the rocks and gets stored in them. The percolating rain water having been charged with carbon-di-oxide and other organic acids, gradually breaks the rock into its constituent particles making it more and more permeable to water circulation and storage. This process sometimes goes on to such an extent as to form deep hollows and bays of such weathered rocks extending to beyond 50 feet without encountering any hard rock. Such weathered zones in gneisses form good receptacles for the storage of groundwater, which may be tapped in wells.

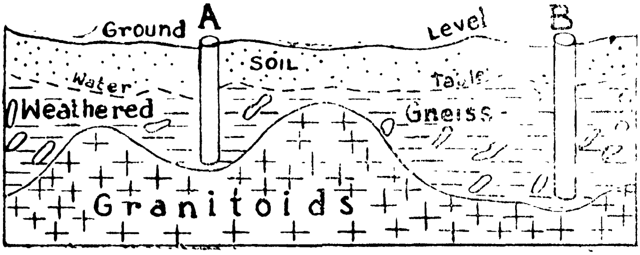


FIG : 2. *Diagrammatic section showing the zone of weathering in Gneisses*

The wells A and B illustrate the case cited above, and it is seen that the well B would give a greater yield of water than the well A since the former is situated in a zone where the mooram not only extends to greater depths, but also to a greater lateral extent. In this connection the occurrence of such bands of weathered rocks to the west of Raichur town round Vedavetti (Lat: 16° -12′-30″, Long: 77° -25′-5″)

village may be mentioned. An investigation was conducted in the area and from observations and data collected from more than hundred wells, none of which having gone through hard rock though the maximum depth reached was more than 35 feet, it was concluded that there were huge pockets or lenticles of such weathered rocks within the body of the gneisses holding big potential sources of groundwater which could be tapped in wells.

The study of topography and the trend and exposures of the gneissic rocks, would reveal the nature of groundwater supply, and it may be found easy in locating in a certain locality such bands of decomposed material by the careful examination of all the existing features, both natural and artificial in locating successful well sites. It should however, be borne in mind that rock features exactly similar to the surface may lie hidden under them and hence proof of depth is not the decisive feature in water finding, for the water found eventually, if at all, is merely that lying near the surface of saturation at the particular spot selected.

The highly jointed and comparatively softer type of rocks form also good reservoirs of groundwater and wells sunk into them beyond 150 to 200 feet are considered as failures, for after that depth the joints and cracks which form the medium of groundwater percolation get scarce and wide apart, eventually disappearing, forming a compact mass of rock.

Many wells in Raichur district have passed through both the type of rocks yielding perennial supplies of water. When a hard type of rock is met with in gneissic area still showing some joints, cracks and cleavages within a reasonable depth, it should not be presumed that any well passing through such rock would be a failure. Further sinking would provide copious supplies of water in case the well has not gone through but has just touched the hard compact rock termed in popular language as '*sheet rock*.'

It has been observed during the course of geological investigations that the gneisses sometimes grade into different types of almost horizontal bands or beds of rocks of varying hardness which can be taken advantage of by sinking wells to pass through to these softer beds of rocks when copious supply of water can be expected. An instance of this may however be cited. An irrigation well sunk in a field and comparatively on a higher ground in the gneissic area, about 5 to 6 miles west of Hyderabad town, had gone in gneis-

ses to a depth of 20 feet and then touched a layer of hard rock with comparatively fewer joints to a depth of 25 feet. The owner apprehended that, after spending lot of money on excavation, the well would prove a failure, but by some stroke of luck the sinking of the well was continued and he found to his great delight that the well, after having passed through hard rock, struck a layer of mooram which yielded copious supply of water. The well was 35 feet deep and is perennial supporting a good garden crop throughout the year. When such conditions prevail and are observed in a locality exposed in nala cuttings or other natural features nearby, the section with the inclination of different beds exposed should be noted ; the depth at which this decomposed layer occurs at the well site in the locality can then be computed. When the well passes through the highly decomposed bed of gneiss or mooram at the depth determined will meet with good quantities of water which may be perennial.

Study of outcrops and their influence on groundwater.

In a granitoid gneissic area with some outcrops at ground level, a close study of the rocks so exposed reveals that they can all be grouped to follow certain definite '*trends.*' These trends of outcrop, though not connected at the surface, may show continuity of hard rock at no great depth from the surface. In such areas it would be advisable to find out the probable trend of these rocks and to select well sites in between parallel trends of outcrops. A well site selected in the same trend or strike as the exposed outcrops is likely to meet with hard rock very near the surface and prove a failure whereas, by locating the site away from it, the depth of decomposition of the rock increases with better chances of locating successful wells.

The groundwater is often controlled by concealed subsurface bodies of some geological formations. It has already been mentioned that the Peninsular Gneissic complex are traversed by innumerable vertical to slightly inclined bands of intrusive rocks of varying thickness, classed as dykes and veins. These dykes which have invaded the gneisses along their zones of weaknesses have a marked effect on the disposition of groundwater. The pegmatite and the quartz veins which are the differentiation products of a *Granite Magma* have by some adjustment of natural forces, forced themselves into the body of these granites as smaller intrusives. These intrusives have also a share in the distribution of groundwater.

Dykes and their effect on ground-water.

The Doleritic and the Dioritic dykes act as sub-surface dams in effectively barring the lateral movement of water to lower levels beyond them. They often occur as intermittent surface outcrops and it is of great importance to gauge their trend and extent and study them in relation to topography and catchment of the area in which a well site is to be proposed. In a sloping ground with a dyke traversing at right angles to the slope, the well site should be proposed on the 'rise' nearest the dyke, but not on its 'fall' side, as the latter would prove a failure due to the groundwater being retained above the dyke as shown in the diagram below :

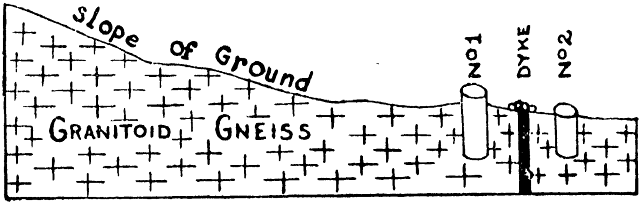


FIG : 3. *Diagrammatic section showing the effect of dykes on groundwater.*

In addition to such simple phenomenon of nature, there are also other complicated features such as one or more dykes cutting and crossing each other or a network of them. In such areas the selection of well sites demands very careful investigation and unless thoroughly grasped and the results interpreted, most of the wells in the area may prove failures or only partially successful, yielding water only for a few months in the year.

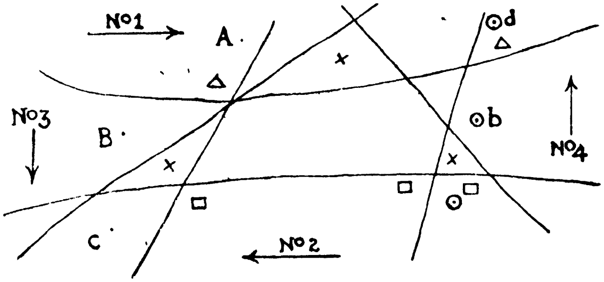


FIG : 4. *Effect of dykes on groundwater.*

A diagrammatic ground plan of such an area is given above with the slope of the ground indicated by arrows. With the slope of the ground directed from west to east as shown by the arrow No. 1, wells A and B would prove successful and C may be partially so since the catchment area between the dykes is relatively small. With the slope of the ground towards north to south (arrow No. 3) the position of wells shown thus △ would be successful ; with the slope towards South to North (arrow No. 4) the wells shown thus ▭ would be most favourable, and with slope towards East to West (arrow No. 2) the most successful wells would be ' b ' then ' d ' and the well ' c ' would be partially successful or may prove a failure. Well sites at ' x ' would prove failures for want of sufficient catchment to warrant a perennial groundwater supply.

Effect of quartz reefs on ground-water.

Quartz reefs and veins also exert almost similar influence in the distribution of sub-surface waters as do the dykes. Taking the case of Khanapur village (Lat. 16° -42′-35″, Long : 77° -1′-5″) Shahpur taluq, Gulbarga district, two well sites were chosen one nearer to a quartz reef which formed part of a tank bund and another a little farther away from the same reef. The well A, though situated nearer to the tank bund and which had gone deeper than the well B, did not yield as much recuperation as the well B. The differences arising between the two wells are due to the presence of quartz reef which has not only effectively barred the groundwater lying above it from flowing to lower levels on the other side, but has also interfered with the available catchment area between the two wells. The well ' A ' having very little effective catchment from that of the quartz reef near it receives but a meagre share of the sub-surface water whereas well ' B ' having a greater catchment, is more favourably situated than that of ' A, ' in receiving a comparatively greater yield of water. The above is a case where the quartz reefs occur in almost vertical positions but the effect of such reefs occurring in inclined positions (*i.e.* reefs having dips) has also been noticed in the case of wells in Gundhalli village (Lat : 16° -42′-40″, Long : 76°-59′-48″) Shahpur taluq, Gulbarga district. Two wells situated only a few feet apart gave quite surprising results in their yield of water. On an examination of these two wells, it was found that well ' A ' met with a thin quartz reef at 15 feet from ground level and, having pierced it, had gone into the underlying rock. The well ' B ' having gone 32 feet from ground level struck the same reef at 31 feet

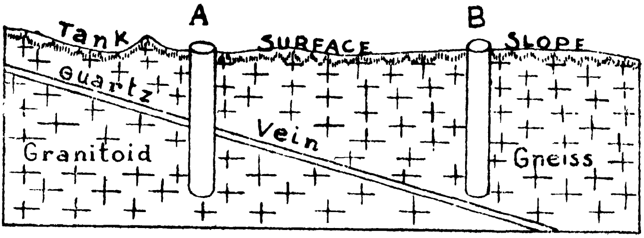


FIG : 5. *Effect of inclined quartz vein on groundwater. (Diagrammatic).*

having just touched the compact rock at that depth. In well 'A' the recuperation was very poor whereas in well 'B' there was ample water supply. This anomaly, curious as it may appear from the surface features, becomes, however, explainable after clearly studying and understanding the underground conditions of rocks as exposed in these two well sections. The inclined quartz reef acting as an impervious bar, has retained above it all the sub-surface water (instead of allowing it to percolate downwards to deeper levels due to gravity) providing a favourable condition in directing a greater and longer flow of water into the well 'B' than into the well 'A,' the rocks pierced below the quartz reef being quite barren of water. It is not possible to detect such underground conditions at the surface, particularly when the inclined quartz reef does not show itself anywhere on the surface nearby; hence in such cases, the location of successful well sites becomes purely a matter of chance.

WELLS IN DHARWAR SCHISTS

In some cases almost vertically inclined schistose rocks occur in varying sizes, from small patches to large bands enveloping the main mass of the granitoid gneisses. These rocks which are highly fissile, conduct the percolating water to great depths. Wells in such rocks have to be excavated very deep and even then they do not often yield adequate recuperation. At Tintini village (Lat: 16°-22′-30″, Long 76°-40′-30″) in Shorapur taluq, Gulbarga district, a well excavated in granitoid gneisses gave very good recuperation at a comparatively shallow depth whereas a few hundred feet off another well excavated to nearly a depth of 60 feet in schistose rocks was almost a failure. Hence such rocks, though forming ideal material for the storage of ground-

water, may yet prove to be poor in their yield because of the presence of planes of schistosity, which are planes of least resistance, through which the percolating water rapidly works its way to great depths. Usually, wells in hard rocks with good joints and cleavages prove to be successful, because, as the water table is reached, the joints and cleavages become scarce and wide apart and almost disappear, acting then like an impervious substratum.

At Bijaswar village (Lat: 16°-33′-30″ Long: 76°-49′-15″) Shorapur taluq, Gulbarga district, two wells situated close by behaved rather in an anomalous way. One well was situated in a band of schistose rocks and the other well on the granitic area. The first well had gone 65 feet but did not yield good recuperation whereas the second well proved successful by yielding good recuperation even at a comparatively shallow depth.

SALINITY IN GNEISSES

Pink gneissic series and particularly their associated representatives are saliferous (deep-seated salinity).

In many parts of Raichur Doab and portions of Surapur taluq, Gulbarga district, the rocks of the crystalline complex yield saline waters which are undrinkable. The Well Sinking Department which had to start its operation first in the Raichur doab was at the very outset faced with this grave problem of salinity which was so predominant and frequent in the area. Even a superficial examination of the area, where in some villages the manufacture of common salts combined with the existence of many abandoned saline water wells, brought home to mind this glaring feature of salinity. The causes of salinity had first to be investigated before any attempt to provide fresh water wells for rural areas could be thought of.

A geological investigation by the Geological Survey Department (which was then under the Special Officer in charge, Well Sinking Department) was conducted and by a careful mapping of the area, all such saline zones that could be detected by the surface indications, and in some cases by the existing brine wells, were demarcated but in places of thick soil cover, for want of natural rock exposures or absence of old wells, such saline patches in them could not be exactly demarcated.

Causes of salinity.

The cause for the salinity in the area appears to be that towards the dying stages of the granitic batholithic invasion, pneumatolytic activity

represented by the Pink pegmatite reefs, introduced saline matter in the invaded region. Hence the pegmatitic intrusions appear to have been accompanied by large quantities of saliferous emanations which subsequently got released in the meteoric circulation. The Pink gneissic series with their associated pegmatites (pegmatitic representatives) seem to have been the last phases of this dying plutonic activity and it is therefore noticed that salinity is much marked in this series than either in the Dharwar schists or the Grey series of gneisses of this complex which are the older granitoid group. The Red syenites, as well as the Red pegmatites, the Pink pegmatites all vined with *Pistacite* yield saline water. The salinity is more marked near the junction zones of the Dharwars with the newer gneisses, as the intrusive activities of the latter and particularly their final Pink gneissic phases have been too predominant and frequent near these zones of weaknesses.

Distribution of salinity.

The distribution of these saline waters is controlled by surface features and underground geologic and structural features of the country; by a careful study, it was found that such salinity gets concentrated along the valleys and particularly along the main drainage basins in the areas. These studies have further made it possible to definitely specify the saline nalas along the banks of which manufacture of edible (common salt) and tanning salts (sulphates, etc.) are being conducted in the majority of cases. Such zones, for instance, may be quoted: In the Raichur doab, the (1) Sarjapur-Guddinhal zone, (2) Sindhnur zone, (3) Chandanhalli-Koratgi zone and (4) Wirapur-Hoshalli area, and in parts of Surapur taluq, Gulbarga district, (1) Baichbal and (2) Chik Hebbal areas. The salinometric brine tests conducted along the courses of these drainage basins showed a definite increase in the percentage of the solutes in the water. This increase is further enhanced along the loops and bends where stagnation of both surface and underground water takes place. At places where the minor nalas feed the main drainage basin, an increase in salinity is also noted.

The results of tests conducted along Sarjapur-Guddinhal zone may here be relevantly quoted in order to give an idea of the nature of salinity. The Baume readings of the brines along this basin in a distance of 10 miles, ranges from 0.500 to 1.50 B. The Brine samples collected from this area show the following analyses:

Brine analyses of samples along Sarjapur Nala within a distance of 10 miles 1, 2 & 3 are brines from bore-holes which are few hundred yards from each other

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12
ANHYDROUS SOLIDS IN 100 C.CS.	1.2034	1.1714	0 6369	1 673	1 508	2 135	0 654	1 435	0 907	0.863	2 009	0.786
1. NaCl	59.10	47.61	25 71	47 16	54 40	44 19	14 41	28.15	23.36	43 33	60 52	37 91
2. $MgCl_2$ ..	3 26	16.02	.	.	1 70	21.13	14 40	.	10 69	.	..	
3. $CaCl_2$	..	7 31	.	.	..	11.95	5.42	.	32 96	..	..	.
4. Na_2SO_4 . ..	.	..	61.00	9 02	.	.	..	44.69	..	6.25	17.81	42.11
5. $MgSO_4$ ..	14 48		..	26 60	23 01		.	12.54	.	16 80	9 08	11.45
6. $CaSO_4$	21 23	26.82	..	15 84	18 60	21 55	16 79	11 14	31 42	31 51	12 25	00.89
7. Na_2CO_3 . ..	..	..	6 51	.	..	.				.		..
8. $MgCO_3$	.	..	3 29		.	.	.	..	.	.	.	..
9. $CaCO_3$.	1 93	2.21	3 45	1 37	2 27	1 17	6 66	1 47	0 55	2.08	0 50	7 63
10. Nitrates	..	.		..	.	.	42 93		.	..	.	.
Total . .	100 00	100 07	99.96	99 99	99.98	99.99	100.61	99 99	99.98	99.97	100 08	100.00

It has to be mentioned here that the percentage of chlorides are usually found higher in brines on the higher reaches of these basins, than in the lower where the bitter magnesium salts predominate. This may be due to the common salt being less soluble than the magnesium salts, which being still in solution are carried away to lower reaches of the same basin. This is also evidenced by the analyses of salt samples and brines collected along these basins.

Soil salinity

The black cotton soil which covers the major portion of the Raichur doab, by its gradual decay gives rise to alkaline chlorides and sulphates which supplement the already existing salinity in the rocks. Regions with thick black soil cover often yield saline or brackish water in wells such as those noted at Wadi, Don Basin, Baichbal area, etc.

Search for sweet water in saline area

The search for drinking water at such places, becomes therefore highly problematical and all the more so, because a considerable portion of the rocks are masked by a thick coat of black soil. Even in such areas attempts have been made in choosing well sites (to yield potable waters) by judiciously avoiding the pistacite veined Pink gneisses and their associated representatives at such places that wells sunk at those sites have been successful in yielding drinkable water. Provided such wells are in constant use and there is no overdraw in them, they may yield drinkable water all through the year, but if once an overdraw is established, there may be a likelihood of some saline spring being drawn into the cone of recuperation thus fouling the once potable water. Absence of draw in the wells in such areas also results in the saline matter getting concentrated partly due to evaporation and partly due to addition of salts, making the water unfit for drinking. This feature is borne out by the existence of many old wells which were yielding fresh water but now have become saline.

Hattigudur village, Shahpur taluq

The village Hattigudur (Lat : 16°-36″-5′ Long : 76°-53″-15′) in Shahpur taluq, Gulbarga district, on the Shorapur-Yadgir road about 10 miles from the former village, is apparently situated in a saline area and the old wells in the village contain brackish water. After a careful examination of the exposed gneissic rocks two well sites were chosen near a nala and away from the contact zone of the schists and granite in a place where the Pink series of gneisses were almost absent. After sink-

ing 10 feet sweet water was struck at that depth. After further sinking to 36 feet the decomposed normal gneisses were showing signs of disappearing and so further sinking was stopped as it was feared that the well may touch some rocks yielding saline water.

Amlapur village, Shahpur taluq.

At Amlapur village (Lat : 16°-43′-10″, Long : 67°-48′-30″) Shahpur taluq, the existing step well to the east of the village is saline. Pink pegmatites with pistacite veins were noticed at the north-west and east of the village and even here a site was chosen with the necessary precautions mentioned already, and the well sunk at the site yielded sweet water.

Pumping and cleaning of wells.

In some cases the old wells which are now saline, but which were said once to have yielded fresh water were taken up and were repeatedly pumped dry and their sides and bottoms thoroughly cleaned before the rains and several times pumped during and after the rains, to wash off as much of the accumulated salts as possible from the cone of recuperation from the fresh percolation of water from the monsoon into the wells. The water, after each recuperation, was carefully tested and after a satisfactory result was obained the well was allowed to recuperate when it was found to be drinkable.

Grey series of gneisses not saliferous.

The grey series of gneisses are not saliferous and have in almost all cases yielded sweet water. But even here an instance of sweet water having been first tapped proved at depth to turn into brackish water which was still drinkable.

Talbedi village, Shahpur taluq.

A well in village Talbedi (Lat: 16°-41′-30″ Long: 76°-59′-0″) Shahpur taluq, passed into 39 feet of decomposed grey gneisses, yielding sweet water but after sinking by only one foot more, it changed into brackish water. On examining the well, it was found that at that depth a slightly inclined vein of Pink pegmatite with pistacite was encountered. The presence of this rock immediately gave the clue for the change in the taste of the water. The sweet water first yielded got mingled with the saline water associated with the rock met at that depth and has resulted in yielding a type of brackish water. Such local underground conditions are not possible to detect even though the area may be bare of soil, exposing only the rocks at the surface and in such cases the sinking of the well should

be immediately stopped when such rocks are met with as was done in the above case. Hence in places where the geological conditions are apparently favourable for the existence of sweet water, local sub-surface conditions may introduce quite an unexpected change in the quality of water due to concealed pegmatites of the Pink series.

Chapter VII

THE BHIMA SERIES OF SEDIMENTARIES.

Introduction

These formations consisting of sandstones, shales and limestones occupy a considerable area of the taluq of Gulbarga district. They overlie the granitoid gneisses and are themselves capped in certain places by the Deccan traps. They are all nearly horizontal and show very little evidence of metamorphism. From a recent geological survey of the area, they have been computed to attain a maximum thickness of about one thousand two hundred feet and have been grouped as follows :

	Maximum thickness Feet
Upper Bhima Series.	
1. Calcareous shales and flaggy limestones	10
2. Red and purple shales and sandstones	300
Middle Bhima	
3. Limestones	550
Lower Bhima	
4. Purple shales, green shales and sandstones	350

At the commencement of the work it was thought that on account of the uniformity of the geological conditions here, the well sinking would be easy. With the progress of work, however, it was realised that this area presented problems even more complicated than those faced in the granitoid gneissic areas. This was mainly due to the fact that the two formations outcropping over the greater part of the area are limestones and shales, neither of which are known to be pervious. The topography resulting from denudational effects of rocks of different physical properties and geological age introduced additional complexities. A region receiving hardly 20 inches of rainfall during the year, cut by innumerable nalas, naturally drained off as surface flow most of the rainfall, leaving only a moiety as 'intake' in favoured zones.

Sandstones being soft and porous retain and yield good water. Generally wells in sandstones present no normal difficulties. The limestones being hard, fine and compact bedded rocks, are generally unsuited as medium for percolation but, being usually traversed at the surface by joints, some amount of water, no doubt, percolates into them. The existence of caverns in limestones formed by the solvent action of meteoric waters, if located, would yield copious supplies of water. These might exist in places with heavy rainfall, but in arid districts they are scarcely met with.

The shales are most unsuited for percolation on account of their very low porosity. These rocks are however traversed by joints through which the surface waters descend to greater or less depths. For reasons given in the opening paragraph of this chapter, wells have to be excavated deep to ensure adequate supplies of water.

Andola taluq.

Taking Andola taluq in particular, where the geological advice was available and where the problem of groundwater was also complicated on account of the structural complexities presented by these in the form of varying thickness of the different members of the series as also faulting and landslips observed in some places, it was not possible to work out a rule of thumb, applicable over a wide area, with regard to the location of the aquifers. The shales reach a maximum thickness of about 250 feet and the limestones themselves are computed to attain here atotal thickness of about 600 feet. For this reason, the comparatively simple conditions of the sedimentary series in the western parts of the Shorapur taluq, where the beds are thinner and structural features are consistent over a well-defined area, are not obtained in this part of Andola taluq. In order to determine the permanent water level of the area, the existing perennial wells nearby or the level at which the nalas become perennial, would afford valuable information and, carrying these levels to the sites where wells are to be sunk, the permanent water table at the place can to some extent be determined. This permanent water table lying below the surface more or less may keep on its proportional depth in conformity to the configuration of the country.

Though on theoretical considerations, one could talk of 'permanent water table' in the sedimentary strata, it was found in practice that none existed down to a depth of 100 feet or more from the surface in the area. A water table can exist only when there is adequate rainfall, a fairly flat country

with vegetation that prevents the rain being lost as runoff and a top porous or jointed strata facilitating the conduction of water to depths. All these conditions are conspicuously absent, especially in parts covered by these shales. It was also observed that wells in shales give some dependable lateral springs at an average depth of 30 to 60 feet from the surface but the strata below are often devoid of water, the greater depth serving mainly as cisterns to collect and keep water. The wells if they are not drawn beyond their '*optimum*' yield stand the chance of withstanding droughts.

On account of the highly jointed and fissile nature of the rocks that cover the area, wells had to go deep to penetrate the permanent water table and depths of 60 to 100 feet may not be taken as abnormal. In Shahbad where similar geological conditions exist, the perennial wells have gone to depths of 60 to 90 feet.

False water table.

During the course of excavation of wells, it was often noted that copious supplies of water were encountered at comparatively shallow depths which after pumping from day to day during the course of excavation, dwindled and sometimes almost disappeared. These are mostly the sub-soil water held at the junction zone of the sub-soil and the lower hard rock.

Gudur new general well. Concretions of carbonates & sulphides indicate intermittent flow.

In the general public well at Gudur village (Lat: 16°-59′-0″ Long: 76°-50′-5″), Andola taluq, and several other villages, the presence of concretions of iron carbonates and sulphides in limestones corresponding to the depth of the water table at the old well were noted. These are concluded to be the result of intermittent and insecure flows of water at this level, such concretions being formed as precipitates during dry weather or drought when the depleted water is unable to carry the mineral matter in solution and deposit them. This often results in the blocking of joints and pores through which water flows into the well.

Safe test to determine depth of well.

It therefore becomes necessary to determine the dependable water table. After excavating the well to the determined water level, the recuperation should be tested and if found fairly constant and further sinking does not improve the yield it may safely be concluded that the well has gone to that depth at which the maximum quantity that is available at the place is reached. The saturation zone if it exists at all, must lie far below the surface

in the country and it would be impracticable to take draw wells already excavated to 100 feet or more to that great depth. The present source of water which is being tapped is a dependable perched water table capable of yielding the requirements even in drought. The zone of saturation may be at considerable depth from the surface somewhere between 200 to 400 feet. When this depth is reached by the bore-hole adequate water may be available for irrigation purposes. It must be emphasised here that as we have at present no adequate data in this respect, only well directed experiments can disprove or prove the hypothesis.

Drilled tube-wells.

There is no reason to expect salinity in these rocks, but certain villages being situated on basin-like ground covered by a thick mantle of black soil, give rise to brackish waters. This as already pointed out, in the section on 'soil salinity' is due to the percolating water taking into solution the saline matter from the soil, thus yielding brackish water in wells in such areas.

Salinity and brackishness.

It is worth-while giving some cases wherein seemingly anomalous conditions have been noticed, but which on closer examination, revealed the truth of the situation.

Some apparent anomalies and their causes—Dharshanapur village.

Taking the case of Dharshanapur village (Lat : 16° -44′-0″ Long : 76° -42-′0″) Shahpur taluq, where two wells proposed at 50 feet to the north of the existing step-well to the north-west of the village, presented some peculiarities. A plan and section showing the details of the surface and underground features are given below :

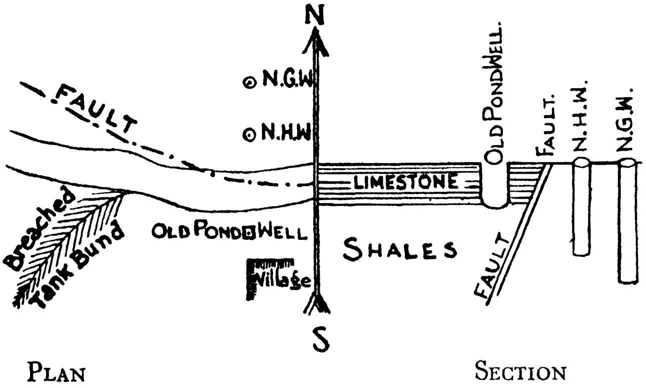


FIG : 6. *Diagrammatic. Influence of fault on groundwater.*

The depth of the old pond step-well is 18 feet with 10 to 12 feet of silt, and it was said that at 16 to 18 feet there were some lateral springs flowing into the well. It was not proposed to remodel this well as it would have cost more and it was therefore proposed to give two new wells 50 feet north of the old well. After sinking the general public and the Harijan wells to depths of 70 and 46.5 feet respectively, the overnight recuperation was observed to be 3 to 4 feet in the former and 18 feet in the latter. From an examination of the area and the information and evidences gathered as illustrated in the diagrammatic plan and section above, it will be seen that the occurrence of a fault between the new wells and the old step-well has brought about an upthrow on the north side of the fault, resulting in the wearing away of all the original limestones, exposing only the underlying shales of comparatively impervious rocks. The old step-well on the other hand has passed into the undenuded overlying jointed limestones, and has just stopped short over the underlying shales which form impervious blanket in the further percolation of the sub-surface water downwards. It is a well known fact that junction of rocks gives rise to springs and consequently the water from the limestones in the form of spring must have been replenishing the well at the junction planes of these two rocks.

A careful study of the surface indications is a prime necessity in the choice of well sites. Sometimes when the rocks are denuded or covered by soil only actual excavations reveal these features and have to be utilised to the best advantage for other excavations in that area. That this fault line has a fairly extensive influence is further evidenced by the wells at Ukanhal village (Lat : 16°-45′-55″ Long : 76°39′-55″) in shales and to some gardens to its south as well as those near Veyoor village (Lat : 16°-44′-0″ Long : 76°-36′35)″.

Experiments and tests on the recuperative power of wells in shales

From points of well sinking operations conducted in Andola taluq, it has been found that the average depth at which water is struck is 30 feet and the overnight recuperation increases by 4 feet and, in some cases, to 7 feet, till a depth of 50 feet is reached. Further sinking resulted in no improvement in recuperation. The table below shows the overnight recuperation in wells sunk in shales.

Mudbal khurd Gen. well		Laknapur Gen. well		Kodchi Gen. well		Jewargi Buzurg Gen. well		Shekapur Gen. well		Shekapur Har. well		Halgadli harijan well		Andola general well		Channur general well	
D.	R.	D.	R.	D.	R.	D.	R.	D.	R.	D.	R.	D.	R.	D.	R.	D.	R.
13	W	19	W	15½	W	27½	W	5	W	23	W	23	W	16	W	37	W
18	2	39	2	20½	2	32	W	11	2	10	2	36	2	25	2	41	2
37	3	51	2	38	6	37	2	17	4	20	5	42	3	30	3	46	3½
39½	2½	55	2½	..	..	58	2½	33	7	27	7½	52	4	37½	5½	52	2
44½	1½	66	3	..	..	..	..	43½	7	36	12	58	4	42½	7	58	4
51¾	1¾	..	..	..	..	..	..	44	8	37	12	60	1½	45	5½	60	2½
70	1	..	..	..	..	..	..	..	..	..	..	..	..	46	5½	61½	2½
..	..	..	..	..	..	..	..	..	..	..	..	..	..	51	6	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	53	4	..	..

W=Water table. D=Depth. R=Recuperation overnight in feet.

The above table brings out the fact that recuperation in shales from point of view of well sinking does not increase with depth, hence it appears that excavation below the optimum depth serves only as a cistern which is so necessary as the villagers usually draw heavy during morning and evening. The poor recuperation at greater depths may be accounted for by these rocks getting more compact, losing much of their joints and fissures, behaving for all practical purposes as impervious substrata. If the rainfall is greater, there may also be a proportionately greater ' intake ' which may exert a greater amount of pressure forcing the water into capillary or sub-capillary openings to lower depths ; but in an area of scanty rainfall distributed over short periods, the percolation is limited and meagre.

Recuperation of shales poor at greater depths.

In some instances, wells which have been completed yielding about 3 to 4 feet of recuperation of water and finally having from 30 to 40 feet of standing water were found gradually to fall in their water level, getting eventually dry as the draw in them was continued. This appears to be due to the cone of recuperation or infiltration being exhausted of water which was being bailed out from day to day when the wells were under sinking. The rocks are sucked dry of water and air gets into the interspaces. Owing to continued failure of rains, the cone had not been replenished and as such, failed for the time being. From experience, it is found that usually a good rainfall brings about a very perceptible rise in water level which dwindles as quickly as it has risen, as this rise was only due to sub-soil seepage. This feature is so common in wells in shales that even the villagers are aware of it and call it '*Mel Nir*' *i. e.*, surface water or soil water, in contradistinction to the more dependable subsurface water. Such wells generally yield their normal recuperation and then function successfully after the area has received two or more monsoonic rainfalls when the joints and fissures in the rocks get soaked once again to the possible limit.

In some areas, the Deccan traps are found to directly overlie the shales and under such situations the junction planes of these two different types of rocks yield better supplies of groundwater. The traps are more or less highly weathered or traversed by numerous joints and cleavages and with their surfaces nearly

Junction of Deccan traps with the shales yields better recuperation.

horizontal the water that passes into them as ' intake ' is retained above the shaly substratum. Provided no steep escarpments are nearby, wells sunk into Deccan traps to touch the underlying shales would prove to yield very good supplies of groundwater.

Greater yields in wells in shales near trap escarpments of moderate height.

There are other cases in which wells in shales situated near Deccan trap escarpments of moderate height have yielded comparatively far greater supplies of groundwater than those in shales far away from the Deccan trap boundary. The weathered and jointed Deccan traps being more permeable to water than the shales below, gradually " pass on " the water to the adjoining shales in the valley. In the Harijan well close to Deccan trap boundary at Mullabad village (Lat : 16° -47′ -0″ Long : 76° -38′ -30″) the yield of water was greater than in the general public well which was away from the Deccan trap escarpment.

Chapter VIII

DECCAN TRAPS

History.

The Deccan traps, as already described elsewhere, are the result of fissure eruptions of molten basic lavas from different vents which flowed to long distances covering hundreds of square miles of the country and solidifying in almost horizontal layers. These horizontal layers range in thickness from a few feet to rarely 100 feet though their normal thickness is from 15 to 30 feet. It is computed that over 2,00,000 square miles of the country in South and Central India are covered by Deccan traps and that they are about 10,000 feet thick. These two facts point to the widespread nature of this volcanic activity as well as to the long period through which it continued. In the Hyderabad State, the Deccan traps cover an area of 32,000 square miles comprising all the districts of Marathwara besides parts of Gulbarga, Nizamabad, Asifabad, Adilabad, Atraf-i-Balda and Mahboobnagar.

From the nature of occurrence and the physical differences observed in the rocks of this series, it is clear that after each succeeding outflow of molten lava, there intervened periods of quiescence when the fresh spread of the lava at the surface had not only time to cool developing joints and cracks, etc., but also sometimes gave occasion for subaerial agencies to impress their effects on the surface, bringing about weathering in rocks, disintegration, denudation and erosion, in much the same way as is going on at present on the surface of the earth. All at once another outpouring of hot liquid lava must have occurred, obliterating and burying everything beneath its onrush. Another period of quiescence must have intervened bringing about the same physical and chemical changes and other concomitant effects on this rock surface and it may thus easily be visualised that such succeeding flows intervened with periods of quiescence, must have continued throughout the early to middle Tertiary (Eocene to Miocene) period of geological time.

The quiet outpourings of molten lava were from different vents over wide areas as is evidenced from the absence of any

crater or vestige of volcanic type of eruption, and that these effusions did not always start from the selfsame vent, nor even from the same locality and perhaps mostly from several fissures functioning at the same time, all point to the fact that the sequence of these layers are not consistent over wide areas and that what is applicable to a particular region need not prove true over an adjacent area.

Locally, however, instead of the hot lava welling out from such vents, vast quantities of ash and scoriae must have been ejected which account for the occurrence of ash-beds in some horizons of these formations.

In addition, the periods of quiescence between each succeeding flow must have in certain cases of such a prolonged nature as to form on the surface pools, basins or lakes, wherein sedimentation of the suspended materials brought down by the denudation and erosion of the surrounding highlands, and as well as chemical precipitates must have been accumulating besides the existence of normal life such as fishes, frogs, etc., in them. At this stage, and all at once the scene is again changed by a sudden outflow of the succeeding lava, covering again everything on its terrible onrush. Such were the conditions in those days as are shown by a study of these rocks which, besides, lend proof that these periods were not apparently simultaneous over the whole area, as is evidenced by the haphazard occurrence of these ash-beds, and interbedded sedimentary rocks and as well as their limited lateral extent forming beds of local interest.

From a study of the scarps of the Deccan trap plateau and correlating the sequence of the flows according to their physical characters of weathering, it is noted that this sequence holds good over a well-defined area which may be of the order of a few hundred square miles. The beds are horizontal and the sequence can therefore be expressed in relation to the Mean Sea Level (M.S.L.) at which the different types of rocks occur. This sequence of the layers, however, changes along some well-defined line, where another set of succession holds good. It is not possible to say if this difference in sequence is due to faulting or to the foci of the fissures of eruption being different. For our purposes it is adequate to recognize that in the Deccan trap area, there are distinct '*zones of validity*' of any particular sequence, the understanding of which is of paramount importance in the study of subsurface water for that area.

Problem of Groundwater in Deccan Traps

As was already pointed out in the genera lintroduction of this paper, the groundwater circulation in an area is dependent upon many factors, such as rainfall, soil cover, topography, texture and type of the underlying rocks, etc. In search for groundwater the cumulative effect of geological conditions and the physiography have to be fully appreciated and taken into account.

Disposition of rocks

The Deccan traps are composed of a number of horizontal layers with the contacts of the two successive flows being very perceptible and sometimes very sharp. The Deccan Basalts are nearly uniform in composition but in their physical characters they show marked variations, in colour, texture, and in their mode of weathering, etc.

Types of rocks and their weathering.

The common mode of weatherig of these rocks is the '*spheroidal*' weathering, by exfoliation into roughly concentric shells around a '*core.*' The harder rounded blocks constituting the core often get released from the decomposed matrix, and are strewn as surface debris. The decomposed shell forms the soil by further disintegration when exposed to sub-aerial weathering.

The vesicular type of rock is the next prominent in the area, which forms sometimes a very important bed from point of water bearing capacity. The vesicles sometimes get scarce or are crowded so close as to form by further weathering and decay into lateritic (surface) or mooram-like material. Druses of zeolites* are usually found within these cavities.

Prismatic or columnar jointing is also met with in these rocks but the most common type is the hard massive basalt with jointing. Certain types of rock seem to have developed more pronounced horizontal joints constituting a sort of bedded rock.

Besides the above, there are other cases of weathering giving rise to soft friable material of variegated colours of blue, dark blue, brown, cream, etc.; and brick red to blood red friable mooram-like material classed locally as lithomarge, and to soft or compact mooram-like rock filled with zeolites.

*Zeolites are hydrous silicates of alumina with other oxides usually alkalies. Their specific gravity ranges from 2 1 to 2 9. Minerals such as Stilbite, Apophyllite, Heulandite, Natrolite, Chabazite, all go by the name of zeolites.

These beds, as will be seen later on, are very important from point of their water holding and yielding capacity.

Secondary minerals.

Secondary minerals are found in abundance filling the cavities and joints of these rocks, of which the zeolites are most common ; quartz or rock crystal and cryptocrystalline or amorphous varieties such as chalcedony, agates, cornelian, heliotrope, bloodstones, jasper, etc., occurring as fillings in druses come under this category. Glauconite is a green coating round the kernels which are often mistaken for copper salts.

Presence of zeolites indicative of an aquifer, whereas quartz of limited water supply.

The presence of these zeolites particularly in the cavities of rocks, and in their altered types of mooram-like* material indicates the abundance of water circulation. Inversely the presence of amorphous silica denotes a restricted flow of water circulation. The presence of such minerals therefore is a useful indication of groundwater.

Underground water in Deccan traps.

From the foregoing remarks about the occurrence and weathering that has followed in these rocks of Deccan traps it becomes clear that a search for underground water narrows itself in its geological aspect to the location of decomposed mooram-like layers which are porous, and occur as well defined layers amidst hard traps. For a proper understanding and location of such water bearing rocks, a study of all the available sections in an area nearby should be conducted and their sections with regard to their differences in physical characters that are noted at various depths in relation to Mean Sea Level (M.S.L.) should be worked out, and plotted so as to be available as a base on which calculations may be made to arrive at depths at which groundwater may be tapped in this area. Side by side with this M.S.L. of the layers in the perennial wells in the area, the rock types occurring in them should be noted to check up with the geological section of the area that was obtained so as to note their corresponding water holding capacity at various M.S.L.'s.

Influence of physiography.

The distribution of water underground is a function of several complex factors. In the trap-area, one of the important factors controlling

*The term ' Mooram ' is here loosely used to denote a much decomposed rock which does not retain its original characters and is nearly completely altered. It is often pink or red with various shades of these colours and frequently contains the secondary zeolitic minerals Mooram in which these zeolites are frequent are described as zeolitic mooram. They are quite porous and are often hardened These hardened zeolitic mooram layers are generally good aquifers.

underground water (*i.e.*, the geological formation) shows a uniformity of character over more or less wide area. On this account a good part of the story of the distribution of underground water becomes intelligible when systematic work has been carried out in the area. Other contributory causes, some of them equally or more important such as rainfall, physiographic peculiarities have also a great influence on the sub-surface water. When a layer is described as an aquifer, it is meant to convey, that on account of its physical characters, that layer is capable of retaining and yielding much more water, comparatively, than other layers in that locality, provided the place is situated in an area of abundant rainfall, and the possibilities of the porous layers getting saturated are great. Whenever we have to deal with regions of scanty rainfall situated in the famine zone, we are confronted with complexities where the other factor, *viz.*, physiography, exercises a very great influence in the distribution of the sub-surface water. There seems to have been a misunderstanding that in the Deccan trap area, any soft aquiferous layer must yield adequate water ; and by penetrating the porous strata at any place, adequate supply should normally be met with. When the rainfall is meagre, and the configuration of the country is very irregular, resulting in a great deal of the rainfall being lost as run-off, the chances of the aquiferous layer getting saturated fully are very meagre. Under such circumstances, it becomes necessary to pay special attention to the selection of sites, so that the best advantage is taken of the physiographic conditions to ensure the maximum supply of water from the porous layer.

Systematic work on this line that has been carried on in this area in various places is given below which illustrates and brings home vividly the condition of groundwater distribution in these trappean formations. Logs of well sections have brought out the fact that usually the zeolitic mooram-like layers have formed into good aquifers and the wells passing through them have yielded good recuperation, and supply of water. When studying the natural sections from scarps or other cuttings at different places the successive layers are easily made out by their specific characters, which warrants our assuming that the nature and sequence of the beds so noted also continue into the plateaux themselves.

The names given here are purely descriptive, based mostly on weathering and do not bear any petrological significance. Locally however, it is not unusual to find a greater alteration

or weathering of the layers, which may go to impose a certain anomaly within the area.

Sequence of trap round Osmanabad.

A natural section from scarps to the west of Osmanabad town reveal the following nature of the rocks.

2,214 to 2,197	Weathered jointed rock.
2,197 to 2,172	(2,160) *Pink to reddish mooram.*
2,172 to 2,164	Much weathered jointed rock.
2,164 to 2,132	Compact jointed rock.
2,132 to 2,118	Weathered jointed rock.
2,118 to 2,090	Much weathered rock with exfoliating boulders.
2,090 / 2,109 } to 2,075	(2,070) *Mooram, friable at top.*
2,075 to 2,045	Comparatively weathered, compact rock at places bedded.
2,045 to 2,029	Compact jointed rock.
2,029 to 2,018	Compact rock.
2,018 to 1,972	(1,962) *Mooram, harder towards the bottom :*
1,972 to 1,962	Weathered jointed rocks in parts exfoliating.

The rocks in italics indicate aquifers.

Interbedded mooram-like beds forming water bearing rocks

As may be seen from the section given above, it is obvious that softer beds and beds of mooram-like nature lie interbedded between them and provided such beds receive sufficient amount of water by percolation through the overlying rocks, they form into good aquifers. It is also observed that such thick beds of interbedded mooram-like layers usually persist to some reasonable lateral extent and may likely pinch off or disappear elsewhere. From the section and the levels given within brackets, these beds are also seen to vary in their thickness from place to place and considering all these features, it must be borne in mind that apparent anomalies may be met with in a locality. It is therefore essential that as many sections as may be available in an area have to be taken and recorded and each of them applied to the respective place within its close proximity in the location of successful well sites and in their forecast regarding the depths at which aquiferous strata may be met

with in them. Such sections can eventually be pieced together to form one complete whole.

Perennial wells in Osmanabad and its environments.

The perennial wells at Osmanabad are due to the existence of a softer bed of mooram between levels 2,090 to 2,075 M.S.L. This bed is exposed on the edges of the nala which runs through the town and from which several springs seep out.

The Police Lines draw-well, whose mouth is about 2,145 feet above M.S.L. has been sunk after advise to a total depth of 70 feet *i.e.*, 2,075 M.S.L., when it resulted in yielding sufficient supplies of water. This is again due to the well having pierced the mooram layer occurring between the levels shown in the section, but which at that place has thinned into a bed of 8 to 10 feet thickness.

Provided the sequence holds good, it would be possible to forecast the depths at which such porous beds are available at a comparatively greater or lesser depth in a particular locality, by taking the levels and referring them to the section given above.

Tuljapur town and its water supply by wells.

Tuljapur town (Lat: 18°-1′-0″ Long: 76°-4′-0″) whose average level is 2,070 M.S.L. and situated almost near the edge of a scarp of a plateau, is subjected to constant water famine in spite of the existence of a great number of big wells and several other smaller ones. The water level in these wells falls from 40 to 50 feet below ground level during the months of April and May, and the yields are said to be poor. By a reference to the section given already, it is seen that between 2,070 and 2,018 M.S.L.'s there are no rocks capable of forming into good aquifers. Below 2,018 and down to 1,972 there occurs a bed of mooram. Though the wells in Tuljapur have gone much deeper from ground level, they have not penetrated this layer of mooram to ensure a good supply of water. In addition, the physiographic feature of the situation of the town of Tuljapur right on the edge of a plateau, as mentioned already, has no doubt militated against the good supply of groundwater.

The thickening and thinning of these aquiferous beds markedly affect the amount of water that can be tapped in them, bringing about in some cases certain anomalies in a locality, though in most cases the correlation of natural sections with those of the wells in a nearby area, will almost entirely correspond, excepting, perhaps, in far off places, where they may entirely vary, due to different set of succes-

sion of flows. Due to uneven weathering of the surface rocks and their differential erosion forming an uneven surface which may subsequently get covered by the succeeding layer of lava flow, it is but natural to expect conditions as brought out in the diagrammatic section below :

The sequence of beds given below are in the order of flow, the oldest being at the bottom and the youngest at the top. Taking the case of bores A, B and C, in the diagram, it is seen that A passes through a mooram-like bed at its bottom, B has entirely missed the bed as it has all been denuded away at the place, and C has again touched the same detached bed. The bores A and C are successful and amongst the two the bore C would yield greater recuperation of water than bore A, but whereas bore B may prove dry. The presence of aquifers in the bores A and C at their bottom are responsible for the yield of water. The reason for the bore B being dry may be due to the highly jointed nature of the rocks which conduct away the water far below that depth. Hence in rocks with too many joints extending far below the surface, the striking of permanent water table within reasonable depths gets scarce.

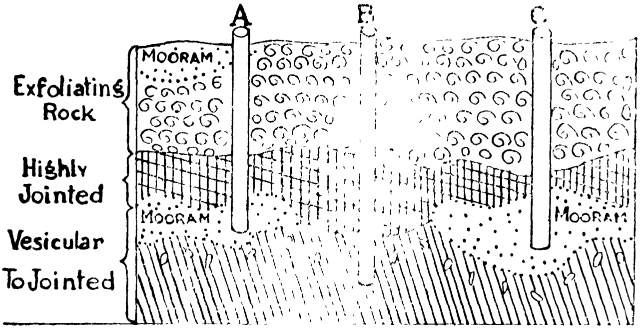


FIG. 7. *Diagram to explain the anomaly in wells in a locality in Deccan trap formation.*

Aurangabad and its environments.

The town of Aurangabad is situated in a valley and is fringed to the North and south by tablelands of Deccan traps, rising abruptly to 3,000 feet M.S.L. The town is between 1,000 to 1900 feet M.S.L., and the country around it abruptly rises into steep plateaus with the escarpments facing the town. Thus the town is very favourably situated, as the major portion of the

surface drainage from the highlands is diverted round the town, inducing a favourable groundwater condition in the area. The sequence of traps with their structure are revealed from the sections taken from the escarpments round the town as noted below :

Aurangabad and Environs

3,040 to 3,024	Hard compact to massive at places vesicular.
3,024 to 3,002	Bedded to compact rocks at places vesicular.
3,002 to 2,985	Highly weathered pinkish vesicular traps.
2,985 to 2,967	Highly weathered exfoliating rocks.
2,967 to 2,963	Weathered vesicular pinkish traps simulating mooram.
2,963 to 2,956	Highly weathered exfoliating rocks.
2,956 to 2,931	Highly weathered vesicular traps.
2,931 to 2,922	Weathered rocks, exfoliating at places.
2,922 to 2,909	Friable vesicular traps.
2,909 to 2,877	Highly weathered rocks showing laminated structure.
2,877 to 2,873	*Mooram-like Material.*
2,873 to 2,834	Hard bedded trap with few vesicles.
2,834 to 2,813	Same as above but highly vesicular and comparatively weathered.
2,813 to 2,791	More weathered looking dirty white and ash coloured.
2,791 to 2,785	Weathered highly vesicular rock, simulating mooram.
2,785 to 2,757	Weathered rocks, exfoliating at places.
2,757 to 2,724	Highly vesicular, weathered rocks simulating mooram at places.
2,724 to 2,614	Hard compact to massive rocks with few joints.
2,614 to 2,612	A hard band of mooram-like material.
2,612 to 2,600	Highly vesicular rock.
2,600 to 2,580	Hard, vesicular to bedded rock.
2,580 to 2,574	Highly weathered, exfoliating at places.
2,574 to 2,565	Highly weathered rocks.
2,565 to 2,544	Hard bedded rock.

2,544 to 2,492	Exfoliating rock in decomposed matrix.
2,492 to 2,487	Weathered vesicular pinkish trap.
2,487 to 2,448	Highly vesicular and weathered, at places soft.
2,448 to 2,383	Highly weathered vesicular trap.
2,383 to 2,375	Weathered exfoliating rocks.
2,375 to 2,309	Bouldery exfoliating rock.
2,309 to 2,295	Highly weathered vesicular rocks.
2,295 to 2,290	Hard band of vesicular rock.
2,290 to 2,250	Highly weathered vesicular rock friable at places.
2,250 to 2,233	Hard and highly vesicular.
2,233 to 2,222	Highly weathered vesicular rocks.
2,222 to 2,185	Exfoliating rocks in highly decomposed matrix.
2,185 to 2,126	Highly jointed sometimes compact at places exfoliating.
2,126 to 2,108	Hard highly vesicular (Lena caves of Aurangabad).
2,108 to 2,102	*Medium hard mooram with zeolites.*
2,102 to 2,075	Highly weathered with patches of harder rocks.
2,075 to 2,060	Exfoliating rock in decomposed matrix.
2,060 to 2,020	Hard compact to massive rock with few joints.
2,020 to 1,997	Highly weathered with patches of Mooram.
1,997 to 1,983	*Medium Hard Mooram (Water).*
1,983 to 1,960	Highly weathered rocks friable at places.
1,960 to 1,950	Weathered vesicular rocks at places bedded.
1,950 to 1,913	Highly weathered, vesicular at places.
1,913 to 1,885	Highly weathered exfoliating with harder patches.
1,885 to 1,880	Vesicular rock but weathered at places.
1,880 to 1,860	Weathered exfoliating rocks.
1 860 to 1,833	Exfoliating rocks weathered at places.
1,833 to 1,825	Harder rock locally weathered.
1,825 to 1,806	Hard compact to massive rock.
1,806 to 1,795	Highly weathered rock.

1,795 to 1,787	Hard compact to massive rock.
1,787 to 1,784	Highly weathered rock.
1,784 to 1,781	Vesicular rocks passing to mooram.
1,781 to 1,764	Highly weathered exfoliating rocks.
1,764 to 1,758	Weathered rocks at places vesicular.
1,758 to 1,736	Highly weathered and friable at places.
1,736 to 1,734	*Red Friable Mooram.*
1,734 to 1,724	Highly weathered with harder patches
1,724 to 1,717	Harder rocks but weathered at places.
1,717 to downwards	Hard compact to massive rocks.

From the above section, it is seen that there are only few beds of mooram between 3,040 to 1,700 feet M.S.L., and that they occur in more or less thin bands, the maximum thickness being 14 feet between M.S.L.'s 1,997 and 1,983 feet. At places where these beds of mooram are either not available due to great depths from the surface or due to places being situated on lower levels than the beds themselves, the only next beds to form the water bearing strata are the highly weathered rocks. In this connection, it has to be emphasised that in places like Aurangabad where, though the rainfall averages 35 inches, the physiographic features are varying from place to place and the distribution of groundwater is so modified as not to be available even in places where favourable geological conditions may exist, and some bores and wells sunk in this town proved failures.

Broadcasting station well, Aurangabad.

There is a well in the compound of the Broadcasting station Aurangabad, whose ground level is 1,931 feet M.S.L. Though the well was sunk to a depth of 64 feet in weathered rocks, it did not yield any recuperation of water. Further amount was invested on this well and a bore was put down at the bottom of the well piercing an additional depth of 40 feet. Even then the recuperation was negligible. The reason for the failure of this well is due to the adverse physiographic conditions of the spot, due to its situation on the ridge of 1,900 feet contour which functions more or less as a water shed. Due to the slope of the ground on either side, almost all the rainwater is lost as 'run-off,' leaving very little for the 'intake.' It would be a different story if there is very heavy rainfall in the area, in which case the porous layer beneath the soil would get adequate supply after the sub-surface rocks in the valley portions are saturated. Thus we see that though

there is a soft stratum in an area that is capable of retaining and yielding water, very little water is really obtained in wells excavated here due to adverse physiographic conditions.

State Railway Hotel, Aurangabad.

A bore hole was put down in the compound of the State railway hotel, and after going down to 80 feet below ground level advice was sought if further boring would prove successful or not. On an examination of the area, it was thought that further boring would not improve the situation much as the physiographic conditions at the place were adverse—almost similar to those at the Broadcasting House mentioned above. The boring was, however, continued to a total depth of 110 feet without materially improving the yield. The mouth of the bore was 1,868 feet and the bottom 1,758 feet M.S.L. The log of the bore agreed very closely with that of the natural sequence of rocks arrived at for the area, where between the two extreme levels of the bore, though there exist softer beds, they could not yield any recuperation of water as they were almost dry. To the north-east of the State Railway hotel, within a distance of about 200 yards, is a well in a valley by the side of a nala, whose mouth is 1,818 and whose bed is 1,791 feet M.S.L., with water level at 1,803 feet M.S.L., *i.e.*, 12 feet of standing water. This well is supplying water to the hotel, but during summer, the yield from the well falls down though it does not get dry. On an examination, it was found that, instead of going to the expense of putting bores at places of adverse physiographic conditions within the compound of the hotel, this well could further be deepened, as below 1,787 feet M.S.L. further softer rocks would be met with down to a level of 1,724 feet M.S.L., as is evident by the natural sequence of the rocks given above. As greater quantities of water would be needed by the hotel, it was deemed worth-while to sink the well to 1,734 or 1,724 feet M.S.L. when good quantities of water would be available. But, instead of taking the advice, another bore to the southwest of the hotel was put up by the advice of one water diviner who predicted that copious supplies of water would be met with at 70 feet. The second bore went down to more than 80 feet, but even at that depth it proved dust dry. Now the railway authorities are thinking of deepening the well recommended. The yield of water in this well is, from the softer beds between 1,806 and 1,795 M.S.L., which is saturated with water at the place but the same bed met with in the bore holes has proved dry which again go to emphasise that a bed which may be aquiferous at one place may be non-aquiferous at

another place due to adverse physiographic conditions. Hence it becomes imperative to carefully study the physiographic conditions side by side with that of geological nature of the rocks to arrive at successful selection of well sites in the horizontal trappean formations.

Assay Lines well, Aurangabad Cantonment.

The Assay Lines well within the Aurangabad Cantonment area is physiographically very well placed, which, combined with the favourable geological nature of the rocks below 1,806 feet M.S.L., has proved to be almost perennial. The collar of the well is 1,794 with water level at 1,812 feet M.S.L., *i.e.*, 18 feet of standing water. This well is said to yield approximately 10,000 gallons of water per hour with a slightly reduced supply during summer months. The water in the well even under heavy pumping maintains a depth of 5 feet. It is seen that the well, after penetrating hard rocks to 1,806 feet M.S.L. has passed into softer aquiferous layer to 1,794 feet M.S.L., corresponding in sequence to the section in the area.

Military wells at Aurangabad Cantonment.

A well by the Military authorities was put up near Bibi Mukbara to supplement the water supply to the extra infantry stationed at Aurangabad Cantonment. At their request, the place was examined and after finding that the location of the well was favourably hit at, it was advised to sink the well to a total depth of 51 feet. The collar of the well is 1,911 feet M.S.L. and it was forecast that more or less at 25 feet from ground level water may be tapped. The well has gone only to a total depth of 40 feet, yielding about 20,000 gallons of water per day in summer. Due to monsoon, the water in the well could not be easily emptied and further sinking to the maximum depth of 51 feet is contemplated during the summer months.

Banwadi Military well, Aurangabad Cantonment

Another well by the same cantonment authorities was under sinking within the cantonment area near the village of Banwadi to supplement the water supply. The location of the well is also very favourable and it was advised to sink the well to a total depth of 60 feet, *i.e.*, to 1,724 feet M.S.L. when it would yield good supplies of water. The rocks in the well though agreeing in all respects with that of the natural section proved to be harder to a depth of 46 feet due to local patches of the harder rocks in comparatively softer material, yielding only poor recuperation. On a second examination, it was emphasised with the help of the natural section, that the well is sure to touch softer materials within the total depth advised to be

sunk and that sinking may go on without any cause for apprehension. At 46 feet, a hole for blasting going down to a little more than one foot, began to spout out water from below, showing the existence of aquiferous layer below at exactly the level given in the natural section. The hole had to be plugged down to facilitate excavation of the sides of the well to get at the underlying aquiferous rock.

The importance of working out the sequence of trap flows in an area in order to arrive at a correct understanding of the distribution of groundwater, has been amply borne out by the foregoing examples and it must therefore form one of the matters of paramount and primary study which needs no further emphasis.

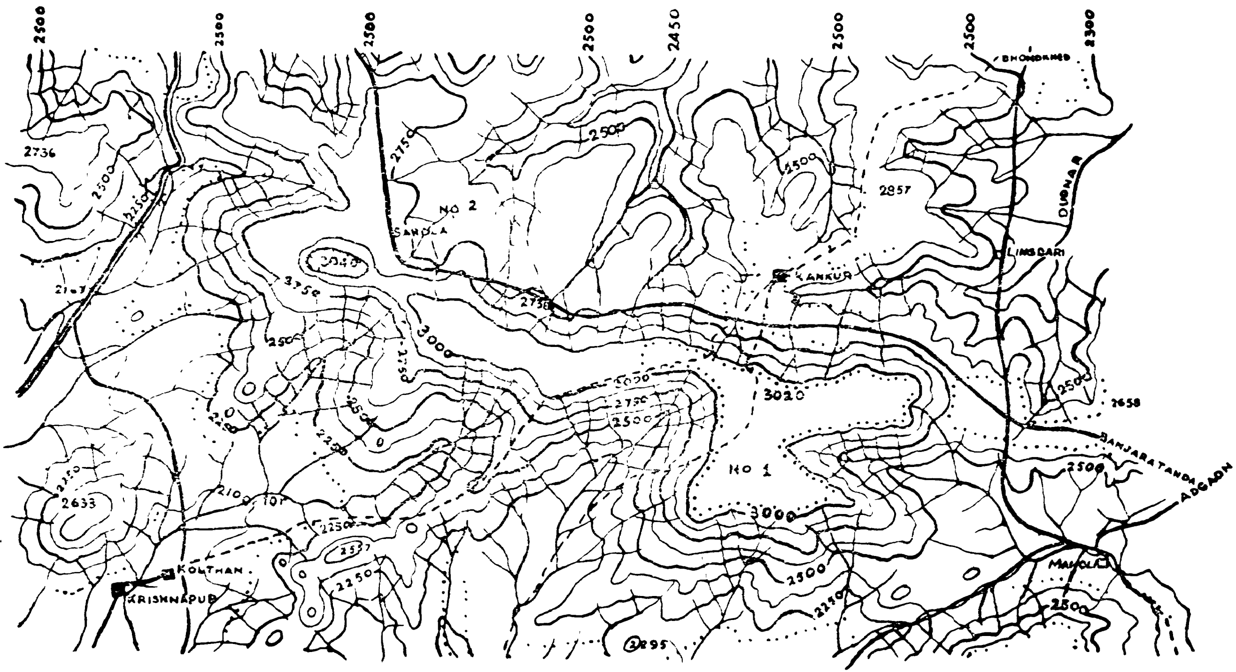
The sequence of rocks plotted from M.S.L.'s 1,950 to 1,700 along the logs of wells in position in relation to their levels have been shown side by side to bring out lucidly the conditions described.

How such a study is of importance is further evidenced by the following examples.

Sarola and Kankura plateaux. Development into health resorts

On the Aurangabad-Ajanta road, some isolated hills rising up to 3,000 feet M.S.L. constitute attractive summer resorts as they command an imposing scenic view and afford salubrious climate on account of their elevation. Two of the largest of this group have areas of 1.25 and 3.125 square miles thus affording considerable space for the development of small colony. At the desire of the government to convert them into health resorts, the question of locating wells for tapping the subsurface supplies was investigated. A study of the physiographic and the geological features was undertaken and a sequence of the trap flows between 1,340 to 2,000 feet M.S.L. was arrived at after taking several sections and arriving at one dependable correlation as shown in the section already.

Though the geological formations as revealed in the sections indicate layers of porous rock, it has to be recognised that one has to deal with physiographic conditions of the most adverse type. As may be seen from a reference to the plan given here the plateau whose average level is 3,020 feet M.S.L. and numbered for the sake of convenience as No. 1, is hardly a quarter of a mile wide for a greater part of its run towards west, though bulging to about a mile and a half towards its eastern extremity. On account of the fairly steep slope, a great deal of the rainfall on this narrow neck



Plan of Sarola and Kankura plateaux showing Contour intervals : Scale : 1" : 2 miles.

will only be lost as runoff and innumerable rain gullies on the scarp point to the rapid loss of rainwater falling on this plateau. The only place on the plateau where some amount of intake may be expected is the wide expanse to east but from experience in other parts of the Deccan traps, it has been found that wells excavated on and near escarpments have not been successful, as a good deal of the subsurface water, that would normally saturate aquiferous layers, escapes as seepage springs from the exposed faces. The only chance, if any, of locating some water will be in the heart of the widest part of the plateau where, though a perennial supply yielding sufficient water cannot be assured, still in view of the importance of the plateau, it is worth excavating an open well to a depth of 100 feet with a possible chance that saturation of aquiferous layers through successive periods of rainfall may ultimately result after two or three years in affording a dependable supply. The average soil cover on the plateau is from 3 to 4 feet on which there is mainly the vegetation of grass and it is likely that a spot in a depression here may yield satisfactory results. But it must however be borne in mind that failure to locate large perennial supplies is a possibility due to reasons already stated.

The lower plateau whose average level is 2,750 feet M.S.L. and numbered 2 which is to the north of the first one, and about 250 feet below it, is more extensive but still the chances of locating well sites on it are none the less better. From the section it is seen that layers of hard rocks extend from 2,724 to 2,614 feet M.S.L.'s, *i.e.*, to a depth of 110 feet and, even after going to such a great depth, it is doubtful if any good supplies of water can be had, considering the huge thickness of this rock which could not have contributed to water percolation, besides the adverse physiographic conditions imposed on the plateau. The scrap to the south shows a sheer fall from 3,000 to 2,200 feet, *i.e.*, 800 feet, and no beds lying under plateau 2,750 are exposed that side beyond the face of the scrap for other opportunities of these beds getting soaked with water ; hence no well sites were advised on this plateau.

Ashti and environs

The town of Ashti—which is a taluq headquarter in Bhir district—whose average level is 1,950 feet M.S.L. is situated between east Long: 75°-10′ 31″ and north Lat: 19°-48′-9″ and in a valley by the side of Talwar nala with the ground rising gradually all round to form into highlands. The wells in the town presented some anomalies and in order to find out the reason, a study

of the area was conducted. A traverse of the country from north to south was done and all the available sections noted and eventually arrived at a final section as given below:

2,808 to 2,786	Top of plateau. Talus and soil covered.
2,786 to 2,774	Bedded rock with vertical joints (Surface weathered).
2,774 to 2,760	Exfoliating rocks in highly weathered matrix. Sometimes the boulders are also weathered.
2,760 to 2,692	Highly weathered vesicular rocks and friable with zeolites.
2,692 to 2,674	Exfoliating rock in decomposed matrix.
2,674 to 2,628	Exfoliating rock, boulders arranged into columnar structure.
2,628 to 2,452	Big bouldery exfoliating rocks.
2,452 to 2,440	Highly weathered vesicular traps with zeolites.
2,440 to 2,373	Big bouldery exfoliating rocks.
2,373 to 2,361	A local band of pinkish vesicular trap with zeolites.
2,361 to 2,303	Big bouldery exfoliating rocks.
2,303 to 2,209	Thick and thin bedded rock also vertically jointed.
2,209 to 2,140	Highly weathered vesicular to bedded rock with zeolites, here and there mooram-like.
2,140 to 2,102	Exfoliating rock in weathered matrix.
2,102 to 2,076	Very highly weathered exfoliating rocks.
2,076 to 2,051	Very highly weathered pinkish, greenish friable rocks.
2,051 to 2,042	Very highly weathered exfoliating rocks.
2,042 to 2,018	..Pinkish vesicular zeolitic rock friable at places.
2,018 to 1,980	Same as above but harder.
1,980 to 1,965	Local band of weathered rocks.
1,965 to 1,907	Hard compact to massive rocks with few joints.
1,907 to 1,895	A local band of pinkish vesicular trap with zeolites.

1,895 to 1,866	Hard compact rock at places exfoliating into a band of more or less ten feet.
1,866 to 1,858	Local band of pinkish vesicular trap with zeolites.
1,858 to 1,847	Exfoliating rocks.
1,847 to 1,843	Hard compact rock.
1,843 to 1,839	Local band of pinkish vesicular rock with zeolites.
1,839 to 1,816	Exfoliating rock.
1,816 to 1,806	Bedded to exfoliating rocks.
1,806 to 1,794	Local band of vesicular trap with zeolites.
1,794 to 1,790	Exfoliating rocks.
1,790 to 1,763	Grits. (Local intertrappeans?).

The above section reveals no typical beds of mooram or lithomarge-like beds and thus differs from that of Osmanabad areas. The hard rocks exposed at the surface are weathered with huge pockets of porous and friable rocks in the uppermost layers of the trap flow. Most of the wells in and around the town were examined and logged. After plotting and comparing the sections of these wells with that of the natural section given above, the following points were elucidated.

None of the wells, even including the perennial ones, have gone below the average depth of 27 feet nor have they pierced the harder rocks between M.S.L.'s 1,965 and 1,907 feet.

The seven mhot well

The Seven mhot well situated to the north-east of the town more or less half a mile away is said to be perennial, supplying water to seven mhots. The collar of this well is at 1,999.6 feet and the base is 1,968.6 feet M.S.L. with about 8 feet of water. From the section given above it is seen that the well has passed through softer materials which may turn into good aquifers at favourable places. Physiographically, the well is very favourably situated and as the bottom of the well has not touched hard rock, it appears likely that the material below the well would be situated in a sort of weathered basin within the hard rock occurring at the level 1,965 feet M.S.L. As the rocks round the well are porous and as the ground above the well forms into gradual highlands, all the sub-surface water from above is gradually gravitated into the well, keeping on a steady flow and marking the well perennial.

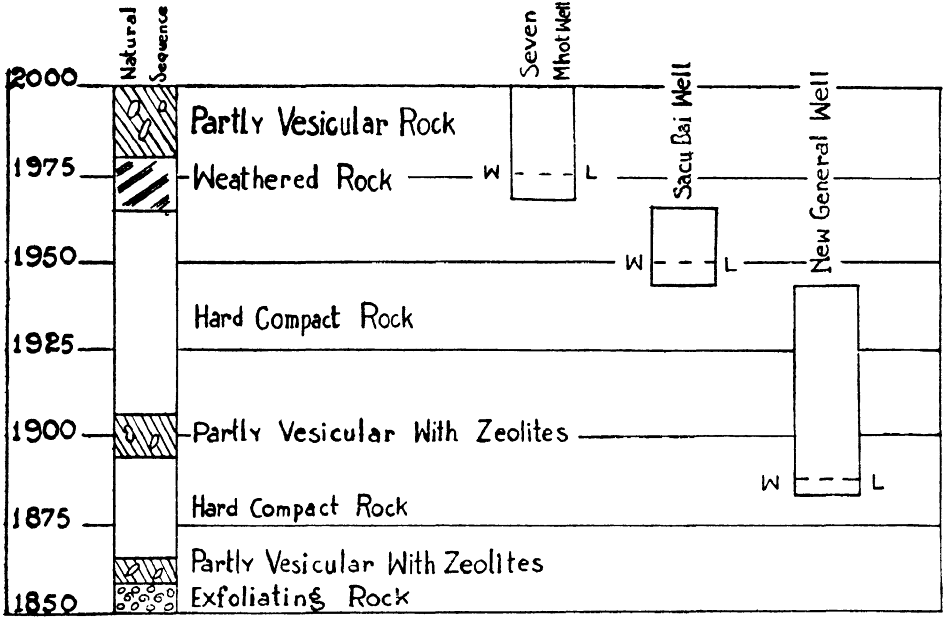


FIG. 9. *Sequence of rocks round Ashti and environs and wells plotted to position: Scale 1 Inch = 50 Feet (Vertical).*

Another well known as Saku Bai well to the east-north-east of the town is also said to be perennial. The collar is 1,967 feet and the base 1,944 feet M.S.L., with 9 feet of water. Though, according to sequence of the rocks the well should have passed in hard rock, it has in reality pierced through the weathered and jointed portions ; this is due to the decay and weathering of the hard rock on account of physiographic conditions. In addition to the favourable physiographic condition around the well, it is to be remembered that to the east of the well, there is a tank which, though now breached, may still hold water during monsoonic months, thus inducing an extra percolation into the porous rocks adjoining the well. Under the above favourable conditions, it is but natural that the well should prove perennial.

Saku Bai well.

Other wells round the town have more or less passed into such weathered and jointed portions of the hard rock and yield water according to the depth of the weathered material and the catchment round them.

But the wells within the town itself are so situated that after a very few feet of softer material, they pass directly into the hard rock with poor yield. Hence these wells go dry soon after the monsoons, and the town is faced with water famine, when the irrigation wells in the valley at the outskirts of the town supply the needs. Knowing the conditions of the rocks underground, new wells were sunk to pierce the hard layer, to touch either of the band of local vesicular zeolitic traps A well having its collar at 1,943.9 feet M.S.L. was sunk to a total depth of 77 feet when between 75 and 77 it touched the zeolitic vesicular rocks corresponding to levels 1,866 to 1,858 feet M.S.L.'s. Further sinking was advised to pierce through the entire thickness of this vesicular trap and then to stop further excavation into the hard rock that may again be encountered. The zeolitic vesicular rock, though porous, has not yielded the expected recuperation as the rock above it is compact and massive with very few joints, resulting in very little water to percolate to lower levels. From experience and observation it was pronounced that after two or three monsoons, the porous bed below would get fully saturated with water and eventually a condition of perennial flow would result. It has been a common experience in the wells in the Deccan trap areas that soon after the monsoons, all the wells get almost filled up with water and this feature gives an advantage in the above well, when the head of water in it would exert a great pressure as to thrust the water laterally in the

porous vesicular zeolitic traps and also in the capillary openings in the hard rock above it.

From the above description of wells in Ashti town, it is seen that under the existing geological conditions, wells in higher levels have proved to be perennial than those at lower levels where it is usual to seek groundwater resources. The existence of the hard rocks between 1,965 and 1,907 feet M.S.L. has formed an almost impervious blanket in arresting the further downward percolation of water due to gravity, maintaining not only a condition of saturation on the overlying porous beds but also inducing a very gradual lateral seepage of that water to lower levels to collect into basins. Springs at the junction of harder and softer rocks are seen at a few places in the nala bed. Normally, one would look for subsurface water in the lowest levels. Due to the peculiar nature of the Deccan traps and the effects of physiographic features, apparent anomalies such as those described are met with, but a careful study helps us to understand these peculiarities.

The small town of Patoda—a taluq headquarter in Bhir district—(Lat : 18° -45′-46″ Long : 75° -29^1-0″) whose average level is about 2,380 feet M.S.L. is also in many respects similarly situated as the town Ashti.

Patoda and environs

The exposed exfoliating weathered and columnar jointed rocks are underlain by a band of pinkish vesicular zeolitic rocks, passing into mooram-like material at many places. Wells towards the ridge have not proved as successful as those situated nearer to the Manjra River on whose banks the town is situated. This is due to the fact that the wells farther away from the river have not only a greater thickness of rocks but also the run-off is great due to steep slopes. Besides the wells situated closer to the river have the advantage of shorter distance of lateral flow of water from the valley than those situated away from the valley.

Few wells situated below 1,900 feet M.S.L. contour more or less about 8 miles south south-west of Ashti town and about two miles north-east of Kharkahat village (Lat : 18° -39′ -55″ Long : 75° -8′ -45″) on the bank of Sina river, have passed into a small local patch of sedimentary grits, yielding perennial supplies of water in them and maintaining garden crops throughout the year. The natural section reveals the presence of such beds between 1,790 and 1763 feet M.S.L.'s corresponding to those of the well sections at the place.

It may therefore be safely deduced that in places where such porous beds are available, the groundwater resources are highly enhanced, and as instances, the casual observations made round Sailu (Parbhani district) may be quoted. The general groundlevel at Sailu, averages about 1,400 feet M.S.L. and a good thickness of aquiferous strata is available at the place within about 100 feet from groundlevel. From cursory study of the incomplete records of bore-holes at the place, it was found that this aquiferous layer ranges to a total thickness of 41 feet, with 20 feet of hard mooram overlying 21 feet of comparatively softer material. These beds form good aquifers and yield good perennial supplies of water in wells. Bore wells have also been successful in this area on account of the presence of greater thickness of porous beds which yield fair supplies of water at comparatively shorter time.

Parenda town—a taluq headquarter in Osmanabad district—(Lat: 18° -16′ -15″ Long: 75° -27′ -0″) whose average level is 1,850 feet M.S.L. shows the sequence of trap flows to be different from that of Tuljapur—Osmanabad area. Here weathered and jointed portions of the rock often form the water bearing stratum provided the joints do not extend to great depths. A study of the wells in Parenda town along with their logs bring out this feature clearly.

From the logs it is seen that the bore-hole in the Tahsil Office has gone to a depth of 95 feet, *i.e.*, from 1,698.82 to 1,594.82 feet M.S.L. without touching any water even after encountering softer beds between 1606.82 to 1,595.82. This is again due to the adverse physiography of the place. Other wells which are plotted to positions according to their M.S.L.'s show that more or less water is tapped at reasonable depths according to their relative positions and the weathering that have undergone in the same rocks touched in them.

Masla khurd

In this village (Lat: 17° -58′ -30″ Long: 76° -0′ -30″) a well sunk to a total depth of 119 feet maintains only 7 feet of water having touched no aquifer.

These cases illustrate that though the rocks are highly jointed and are permeable to water, they do not yield that water because of the absence of a medium in arresting the flow to lower depths.

Springs in hard trap.

In some instances in Deccan trap area wells which have gone through hard rocks have yielded sufficient supplies which rarely failed. These are explained by the presence of certain isolated aquifers

from which water leaks through big cracks into the rocks immediately below it. An instance of this type was observed in irrigation well in Jangaon village (Lat : 18° -45′ -10″ Long : 75° -11′ -45″) Ashti taluq. The total depth of this well is 26 feet. This well of 21 feet diameter, at a depth of 19 feet from ground level, was found to have a spring which was capable of yielding 7 feet of water in about 12 hours. A similar case was noticed at Welhuri (Lat : 19° -3′ -45″ Long : 75° -3′ -40″) village in the same taluq, where a well having gone 66 feet yielded at 24 feet from where harder rocks were encountered, a good spring which is the only source of water in the well. The recuperation from the spring being small, it is not able to cope with the requirements of the village ; besides, the well being situated on the ghats and the catchment round the well being small, the spring dwindles in summer. This phenomenon is very similar to some joint planes in granite yielding large supplies of water.

Selection of well sites in Deccan traps. Influence of physiography.

The distribution of sub-surface water being a complex function, controlled by several factors, of which geological feature is one, others equally or even more important such as the rainfall and physiography, are also to be borne in mind. The latter includes the surface configuration, drainage, catchment and soil cover, about which much has been already said. In a region with good rainfall, one can look for nearly saturated condition of the aquifer, but in an arid country with hardly 20 inches of annual rainfall, only certain protected valleys with some catchment, store of water in the porous strata are met with, while similar strata in areas away from such zones are found to hold very little or no water in them. Hence it is very important that, in the selection of well sites, this point should form a consideration of primary importance.

Escarpments and well sites near them

Usually the traps continue for long distances as a monotonous plateau but end often in steep escarpments. The task of supplying water in the villages in proximity to the scarps becomes very complicated. Usually draw-wells should never be located near escarpments. In such localities if the geological nature of the rocks and other attendant features are favourable, deep tube-wells may be tried to pass to a depth of the valley below the escarpment.

Natural thick vegetation indicative of local ground water conditions.

In addition to the surface and sub-surface conditions which are to be obtained in areas, where well sites are to be chosen some further clue is also available from the disposition of natural growth of vegetation particularly huge broad leaved

trees which send in their main roots to touch the groundwater in the area. These trees have often a well defined directional trend which happen to be lines of disposition of good sub-surface water supplies. In the selection of well sites, in addition to other features, it is also advantageous to be guided by the evidence afforded by these trees and to try and locate sites in the line or trend of such trees. As may naturally be expected, these lines often correspond to the valley or low-lying parts in an area.

In the village Manegaon (Lat : 17-°59′-0″ Long : 75°-39′-0″) Parenda taluq, two wells were excavated one on the rise side of the valley with good catchment and another on the 'fall' side as illustrated in the diagram below :

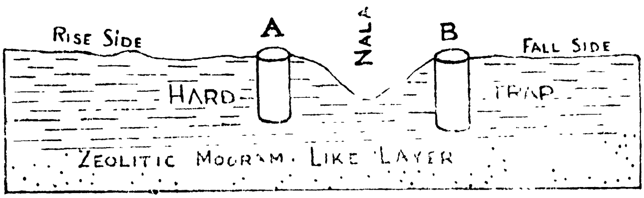


Fig : 11. *Diagram illustrating the influence of water courses on groundwater.*

Manegaon village.

The well A, being 25 feet deep, met with good supplies of water, whereas B did not show any useful recuperation and was therefore almost a failure. This is due to the sub-surface seepage establishing a flow below the nala bed in the same trend as the nala where the horizontal rocks being more jointed and porous constitute the line of least resistance. Very little water appears to have percolated to the 'fall' side in consequence of which the aquifer in well B remains unreplenished. In these horizontal trappean rocks it is found from experience that nalas and even small water courses exercise profound influence in the distribution of sub-surface water in arid regions with scanty rainfall.

Artesian conditions not common in Deccan traps.

The Deccan traps are almost horizontally disposed and so the requisite conditions for the location of artesian wells are very rare. It is however possible that at some places the topography favours the formation of artesian or sub-artesian conditions.

In cases of thick uneven and therefore undulating beds of aquiferous strata which are saturated with water and con-

fined between two more or less impervious beds of traps, the hydrostatic conditions of the water within such porous bed combined with the pressure exerted by the water lying in the highlands of the valley, create sub-artesian effects in the wells pierced in them. Similarly in such saturated beds which overlie the impervious shales of older formation where similar physiographic conditions as mentioned above exist, the water also shoots itself in the form of sub-artesian spring. It may be mentioned therefore, that these requisite conditions should be present in an area where such sub-artesian effects are met with.

Yedrami village, Andola taluq. Sub-artesian conditions.

Such an instance was met with at Yedrami village (Lat: 16°-51′-30″ Long: 76°-32′-5″) in Andola taluq where the new general well, after piercing a fairly thick bed of zeolitic mooram in the Deccan traps overlying the shales, met with sub-artesian effects even at a comparatively shallow depth. Four power pumps with a total capacity of 80,000 gallons per hour could not empty the last 2 feet of water. Water gushed to a height of 8 to 10 feet from one of the springs. The situation of the village being in the head of a protected valley, commanding a good catchment on all sides except the west, has, by conditions imposed as described above given rise to this phenomenon of sub-artesian effect. It is strange that other wells which did not touch this porous bed but which nevertheless have struck water in them have not given rise to any such phenomenon and it therefore follows that, due to the detached nature of the sub-surface water in them, the hydrostatic head is not available in those waters.

Diksal village, Tuljapur taluq. Sub-artesian conditions

In both the general and the harijan wells in Diksal village (Lat: 17°-54′-5″Long: 75°-42′-10″) which have gone to total depths of 92 and 114 feet respectively from ground level and which have touched water-bearing mooram beds at 81 and 96 feet respectively (from ground level) good sub-artesian effects were encountered at those depths with the result that the wells could not be emptied. There are various reasons to account for this phenomenon, but looking at the nature of the country and the rock types, it cannot be pre-supposed that this effect is due to the inclination or dip in the beds. If the question of inclination is entertained, it would introduce another important feature in the depths at which they will be encountered in different places but not at the same M.S.L.'s, as otherwise evidenced in the well at Bhoira village (Lat: 17°-52′-0″

Long: 75°-40′-45″) general well situated about four miles almost due south wherein the same bed, which was encountered at a relative level of 639 feet at Diksal general well, was encountered at the same relative depth of 639 feet without any sub-artesian effect. This absence of sub-artesian effect in Bhoira general well may be due to the detached nature of the mooram bed which has not been saturated with water at the locality despite its situation by the side of a loop of a major water course.

The causes for the sub-artesian effect in Diksal wells may be accounted for as follows. Firstly the mooram beds must have been fully saturated with water; secondly of a consistency to yield a greater proportion of that water and thirdly the beds to be of irregular or uneven thickness at the locality. The thickness of the bed varies from 20 to 25 feet which is considered sufficient to hold good supplies of groundwater. The rocks underlying and overlying them are the compact to bedded types. As already pointed out elsewhere, the mooram beds vary in their thickness from place to place and as shown in the diagrammatic sketch below, the porous mooram bed A, being staturated with water, may maintain a hydrostatic head within it which will result in a sub-artesian effect in wells pierced into slopes. This feature more or less corresponds in simulating a locally inclined porous bed which is so common a feature in tilted sedimentary rocks. The sub-artesian effect in the harijan well was more pronounced than in the general well which is explained by the former piercing the same water bearing bed at relatively lower level than the latter as clearly shown in the diagrammatic sketch below:

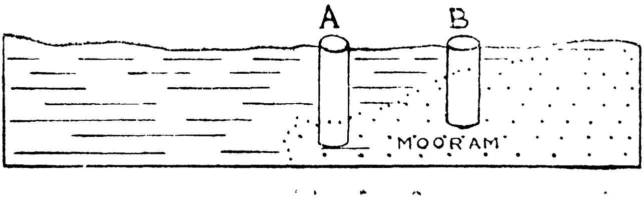


FIG. 12. *Diagrammatic section to illustrate sub-artesian effect.*

Topographically, the village is very favourably situated on a low-lying basin with a pronounced water course which takes a big loop towards the village thus augmenting at

the place the intake of water which may increase its storage normally available from other sources of the catchment area. It may also be noted here that the water though slightly brackish, is quite drinkable.

From the position of these wells, as plotted, it was advised to sink the general well at Tagmachivadi and the Bhoira harijan well to depths of 30 feet in order to pierce the same mooram bed and tap sufficient water which may not be of sub-artesian nature. The wells have been dug to the recommended depths and they have yielded sufficient water to meet the demands. As pointed out elsewhere the condition would improve after two or three years of successive monsoonic rainfall.

It has often been observed that wells which pierced through aquiferous beds yielding good supplies of water have resulted in loss of recuperation or in rare cases gone dry by further sinking into jointed rocks below, due to the percolation of water into such rocks below by gravity. Under such cases, unless the aquiferous beds are very near the surface yielding little or no water there is no use in sinking into hard jointed strata below soft water bearing beds.

Talus and debris at the foot of scarps of Deccan traps.

Usually at the foot of scarps of Deccan traps, good amount of talus and debris along with coarse soils are accumulated to such an extent as to contain sufficient supplies of water which may be available in good quantities. The alluvial fans formed by streams and rivers under such scarps are more valuable as they not only hold water for longer periods but also yield them gradually to form perennial supplies. Such deposits can be taken advantage of by running infiltration galleries in them to augment the water supply. In this connection the water supply of Aurangabad town laid out by Persian Engineers in the days of Malik Amber is worth mention and study. A detailed description of this has already been given in this manual under the heading 'Rock Talus.'

Salinity in Deccan traps.

The Deccan traps are not generally known to yield saline waters ; however, due to local conditions of thick layer of black cotton soil which by further decay, may result in accumulation of salts, imparting brackishness or salinity to the water in that locality. Such examples were noted in the wells at Malumbra (Lat : 17°-56′-0″ Long : 76°-0′-30″) and Tamalwadi villages (Lat : 17°-50′-35″ Long : 75°-58′-20″) Tuljapur taluq.

The salinity or brackishness formed under the conditions mentioned above gets concentrated by gradual seepage from the catchment area of the drainage basins where, in addition, the black cotton soil from the surrounding highlands is gradually drifted down and piled up along the banks of such water courses. This feature becomes pronounced particularly near the loops and bends of such water courses on account of which well waters near such basins are brackish or saline.

Laterite

Laterite* is a porous, pitted, clay-like rock, with red, yellow, brown, grey and mottle colours. It has a hard protective limonitic crust on the exposed surface which is generally irregular and rough. When dug up, the fresh material is comparatively soft and can easily be cut by a spade or saw. In this state, it has often variegated colours and shows vermicular cavities which are irregular and tortuous. When the fresh, soft rock is exposed to air, it is quickly dehydrated and becomes quite hard. Laterite may form from a variety of rocks, the end product containing mainly the hydroxide of iron, alumina and manganese. In the Deccan, due to secondary silicification, a great deal of silica is met with in the laterites. Large areas of the Deccan trap are sometimes covered with a lateritic cap having a thickness up to 100 or 150 feet. In these the laterisation has gone to completion.

The towns of Bidar, Vicarabad and Homnabad are situated on plateaus of laterite overlying Deccan traps. On account of its highly porous nature, most of the water is drained off to lower levels with the result that wells have to go very deep, averaging from 70 to 80 feet, to nearly touch the underlying semi-impervious or impervious layer of Deccan traps before water could be tapped and obtained in sufficient quantities. The great thickness of this laterite without any interbedded impervious layer has therefore given a feature of deep wells in the town.

In conclusion, it may be stated that the underground water supply in Deccan traps resolves itself to the following main sources :

(1) Seepage in the Lateritic zone.

(2) Bigger water supplies at the junction zones of laterite and undecomposed trap.

* "Geology of India" by M. S. Krishnan, 1943, pp. 500-501.

(3) In each succeeding weathered traps, if any, at the junction of the different layers of Deccan traps.

(4) In the vesicular traps and mooram-like layers occurring at intervals and worked out for every area as revealed in the foregoing discussions.

(5) In the inter-trappean beds of grits encountered locally in the area and whose thickness and depth can be worked out as described above.

(6) The ash-beds situated at varying depths and distributed sporadically if encountered in a section would prove water yielding.

(7) The junction zones of the Deccan traps with older formations or land surface, *e.g.*, shales of Bhima basin as detailed above, may prove to be highly water bearing.

(8) Talus and debris at the foot of Deccan trap scraps may yield good supplies of water, an instance of which has already been described in detail under rock talus (Aurangabad ancient water supply).

From the foregoing discussions and examples it is observed that in the trappean areas, the geological formation controlling the underground water shows uniformity of character over more or less wide areas and by a study of this feature combined with the appreciation of the importance of physiographic conditions in arid regions, the problem of locating groundwater supplies in wells becomes fairly simple. It must, however be borne in mind that generalisations may have certain exceptions as indeed every generalisation must have.

To face p. 89.

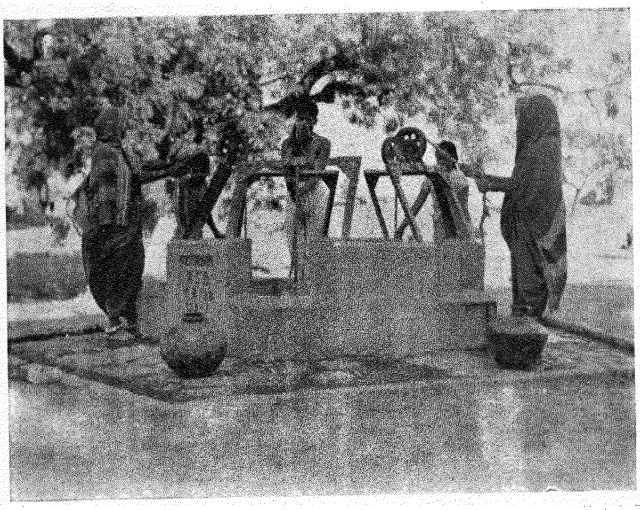


PHOTO PLATE NO. 2.—*A completed well under use. The most hygienic source of water supply provided by the Well Sinking Department.*

PART II

CHAPTER I.

GUINEA-WORM

Guinea-worm is a water-borne disease and is widely prevalent in several districts of the State. The department was therefore, at the very outset, faced with this grave problem of finding ways and means of eradicating this painful, though non-fatal disease.

Introduction.

The larvae of the guinea-worm swim about actively in water and cannot live by themselves without the medium of hosts; in this way they form into parasites. The moment they are ejected in water, they find shelter in the body cavity of crustaceans (cyclops) and undergo further development. In the absence of such cyclops—the intermediary hosts—they die within a short period of three days. It is therefore obvious that, if cyclops can be eradicated from wells and tanks, guinea-worm disease will not exist.

One of the effective and efficient means of preventing the propagation and infection of this disease is by the provision of protected clean drinking water supply to the villages, and the department, in conducting this work, is also directly aiming at the prevention and eradication of this foul and painful disease. In order to control and extirpate this pest as much as possible villages which do not come within the perview of this work, due to their situation outside the Famine zone receiving more than 25 inches of rainfall per annum are also taken up for consideration according to circumstances, and protected wells provided therein, in order to prevent these villages forming into nodal and endemic centres for the spread of this disease. As this work forms one of the objectives of the department, it would be pertinent to deal in detail about the life history of this parasite. The extracts given below are from Manson's Tropical Diseases.

Guinea-worm (Dracunculus mendinensis) is a parasite with a fairly wide distribution in the tropics. It occurs in Africa in the valley of the Nile, Turkestan, Arabia ; in parts of

South America and South India. According to Manson the male worm has only once been found. The female worm measures from 30 cm. to a metre and a quarter, with a diameter up to 1.5 mm. The embryos of the worm are somewhat flattened with a tapering tail, and measures 0.5 to 0.75 mm. in length by 0.07 mm. in breadth.

" The embryos are shed into water by the parent worm, when the human host carrying them near the skin comes into contact with cold water.

" These embryos swim about actively and enter the body cavity of a fresh water crustacean (cyclops) and develop to lengths of 1 mm. The metamorphosis of the embryos in the cyclops takes place from 5 to 9 weeks depending upon the climate. The cyclops containing the larvae of the guinea-worm on being swallowed by man in drinking water, is digested and the parasite activated as it were by the gastric juice of the stomach which had proved fatal to its intermediary host—the cyclops—works its way into the tissues of its new and definitive host. It is now fairly conclusively proved that the life span of the female worm is about a year, conforming probably to the habits of certain species of cyclops which under natural conditions serve as its intermediary host.

" The parasite on attaining maturity, migrates generally to the legs and feet. These are the parts most likely to come into contact with puddles of water, the medium in which the cyclops—the intermediary hosts—live. Occasionally the guinea-worm fails to pierce the integument of the host, sometimes she dies before arriving at maturity when she may give rise to abscess or get critified (impregnated with salts of lime).

" The haunt of the female guinea-worm is the connective tissue of the limbs and trunk. When mature and prompted by instinct she proceeds to bore her way through the tissue, travelling downwards. Occasionally she presents on the scrotum and rarely in the arms; exceptionally in other parts of the body or even in the head. In some cases the appearance of the worm at the surface is attended by fever and itching sensation (urticaria). The onset of the skin eruption is generally at night, before blister or other localising signs are noted. Arriving at her destination, the female worm pierces the inner skin. As a result, some irritating secretion a small blister containing numerous embryos now forms and elevates the outer skin over the site of the hole in the inner skin. The

blister gradually ruptures disclosing a small superficial erosion ½ to ¾ inch diameter. At the centre of the erosion a minute hole large enough to admit an ordinary probe is visible. Occasionally, when the blister ruptures, the head of the worm is seen protruding from this hole ; as a rule however, at first the worm does not show. If now we douche the neighbourhood of the ulcer with a stream of cold water expressed from a sponge and as the water falls in the little hole, in the centre of the eruption is seen in a few seconds a droplet of fluid at first clear, later milky up through the hole and flowing over the surface. Sometimes instead of this fluid, a small pellucid tube about 1 mm. in diameter is projected through the hole in response to the stimulus of the cold water. When this tube has projected an inch or thereabouts, it gradually fills with an opaque whitish material, when it ruptures and collapses ; the fluid spreading over the surface of the eruption. If a little of the fluid either that which has welled up through the hole or that which has escaped from the ruptured tube, be placed under the microscope it is seen to contain myriads of Dracunculus embryos lying coiled up, almost motionless, with their tails projecting in a characteristic manner If now a drop of water be instilled below the cover glass the embryos may be observed to unroll themselves and in a very short time, to swim about with great activity. If the douching be repeated after an hour or longer a further supply of embryos can be obtained ; and this can be continued from time to time until the worm has emptied herself. Apparently the cold applied to the skin of the host stimulates the worm to contract and thereby force out her uterus inch by inch, until it is completely extruded.

" Should the worm become injured or lacerated while lying in the sub-cutaneous tissues, several local reactions may develop. The part becomes extremely painful, inflamed and odematous and cellulitis due to secondary bacterial infection, may result.

" Formerly it was the custom, as soon as a guinea-worm showed itself, to attach the protruding part to a piece of wood and endeavour to wind her out by making a turn or two of this daily. Sometimes these attempts succeeded ; just often the worm snapped under the strain. The consequences of this accident were often disastrous. Myriads of young ones escaped from the ruptured ends into the tissues, cause violent inflammation and fever followed by abscess and sloughing, ensued ; weeks or months perhaps elapsed, before the unhappy victims of this rough surgery were able to get round.

Too often, serious contractions and ankylosis from loss of tissue and inflammation and even death from septic trouble resulted. If a guinea-worm be protected from injury and the part she occupies be frequently douched with water her uterus will be gradually and naturally forced out inch by inch and emptied of embryos. Until this process is completed she resists extraction ; possibly the hook at the end of her tail assists her to maintain her hold. When parturition (giving out of embryos) from fifteen to twenty days is completed, the worm is absorbed or tends to emerge spontaneously. A little movement if practiced then, may aid extrusion. Movement however, must not be employed so long as embryos are being emitted. The completion of parturition can be easily ascertained by the douching experiment already described when located by X rays and collargol, the worm may be dissected out.

" The parasite may be killed by injuring her by means of a syringe, with solution of bichloride of mercury, 1 in 1,000, when after twenty four hours, extrusion can usually be easily effected. If the worm has not shown herself externally, but is felt coiled up under the skin, the coils should be injected through several punctures, with a few drops of the same solution. Fairly and Glen Listen advocate aspiration of the blister fluid previous to extraction, followed by precautions to avoid sepsis. They advice actual excision of the worm if lying convoluted in a limited space, failing this, intermittent traction of the worm should be combined with massage. The sub-cutaneous injection of 9 to 10 min : of 1 in 1,000 adrenalin hydrochloride immediately relieves the distressing prodromal symptoms from absorption of toxins, such as Urticaria and Asthma.

" Intravenous injections of Tartar emetic appear to exert little or no influence upon the dracunculus.

Prophylaxis

" From what has been stated with regard to the role of cyclops, it is evident that prevention is merely a question of protecting drinking water from pollution by guinea-worm patients. Leiper has shown that by raising by few degrees the temperature of the water in which the cyclops are living, the crustaceans are killed. He suggests heating by a portable steam outfit of guinea-worm infected wells. Alcock has found that the addition of a trace of Potash to the water is equally effective."

In cases where new wells are provided to villages, the question of infection and the recurrence of the disease is al-

together prevented. But in cases of private owned step-wells, which cannot all be remodelled or converted into protected draw-wells, due to prohibitive cost, besides the protests of the owners on account of their sentiments and ignorance advice and propaganda are resorted to. The measures to get the guinea-worm infection under control are as follows :

(1) The water in wells for drinking purposes should be thoroughly boiled as the larvae along with the cyclops perish at 175° F.

(2) The wells should be periodically sterilised with unslaked (quick) lime, a small percentage of which is sufficient to kill both the host and the guest. 50 grains of lime for a gallon of water is sufficient. The quantity of water in the well is calculated and the amount of quick lime required calculated according to the above proportion is added to the water, completely mixed and sterilised. If there is too much water involving the use of large quantities of quick lime, then the water may be bailed or pumped out as much as possible and the required quantity of quick lime added to the water in the well. When this process of sterilisation is conducted, the alkaline water in the well should be injected into all the crevices of the well, so that any cyclops that may be lodged therein may be completely destroyed.

Perchloron, Potassium permanganate and Copper sulphate are also advised as good sterilisers of such waters. Usually 3 lbs. of perchloron is enough to sterilise 100,000 gallons of water.

Other interesting methods of combating the guinea-worm carrying cyclops are to stock step-wells with species of Cyclopedocidal fishes, which destroy these infected crustaceans. They are :

(1) Barbus (Puntius) puckelli.
(2) Barbus (do) ticto.
(3) Barbus sphore.
(4) Barbus chola.
(5) Barbus Phutunio.
(6) Rasbora Doniconius.
(7) Lepidocephalocythys Thermatis.
(8) Nemochilus.
(9) Haplochilus Lineatus and Panchax.
Lal Jingra (Hindustani)
(10) Anabas Scandens. Kavi (Hindi)
Kazana (Marathi).

The complete life history of the guinea-worm is not definitely worked out, but so far as is known at present the life-span of the parasite is said to be 18 months, and on this basis it may be concluded that if wells are kept free from cyclops for a minimum of this period, the infection of the worm can be altogether extirpated.

Some very interesting data, arrived at by a close investigation of the incidence of guinea-worm in a few villages chosen at random in Alland paigah are tabulated below:

TABLE NO. I.

7 Table I shows that the infection is more commoner in men, than in women, and this may be accounted for by the fact of the former moving about from place to place.

Serial No.	Names of villages	Taluq	Males		Females		Total		Percentages
			Population	G.W. Patients	Population	G.W. Patients	Population	G.W. Patients	
1	Tup Borgaon ..	Alland ..	318	68	264	39	582	107	18.4
2	Salgar	do ..	632	139	600	82	1,232	221	18.0
3	Kunsalgi or Kunsavali	do ..	131	27	134	12	265	39	15.0
4	Bolegaon ..	do ..	351	117	302	54	653	171	26.2

TABLE No. II.

Number of Previous Attacks.

Table II shows that persons once infected do not become immune from further attacks. On the other hand it is seen that persons attacked once are more prone to further attacks.

Serial No.	Names of villages	Taluq	Cases without any previous attack	Cases with 1 previous attack	Cases with 2 previous attacks	Cases with 3 to 10 previous attacks	Cases with more than 10 attacks	Total
1	Tup Borgaon ..	Alland ..	40	13	9	34	11	107
2	Salgar ..	do ..	104	36	10	46	25	221
3	Kunsalgi ..	do ..	14	10	..	7	8	39
4	Bolegaon ..	do ..	84	31	2	25	29	171

TABLE NO. III.

Number of Worms at a time.

Table III shows that a person is liable to have an attack of more than one worm. The highest number of attacks suffered simultaneously by any individual so far recorded is 50.

Serial No.	Names of villages	Taluq	Cases with one worm	Cases with two worms	Cases with three worms	Cases with four worms	Cases with more than four worms	Total
1	Tup Borgaon ..	Alland ..	82	15	6	2	2	107
2	Salgar ..	do ..	176	30	12	2	1	221
3	Kunsalgi ..	do ..	31	6	2	..	..	39
4	Bolegaon ..	do ..	125	34	6	3	3	171

TABLE No.

Situation of

Table IV shows the situation of the worm in the body, mostly on

Serial No.	Names of villages	Taluq	HEAD & NECK			UPPER EXTREMITY			
			Head	Chin	Neck	Axilla & shoulder	Arm	Elbow joint	Fore-arm
1	Tup Borgaon ..	Alland ..	..	..	..	..	..	..	..
2	Salgar	do ..	..	..	..	..	..	..	..
3	Kunsalgi ..	do ..	..	..	..	..	..	..	..
4	Bolegaon ..	do ..	..	..	..	..	..	..	..

No. IV.

the Worms.

the lower extremity and particularly round the ankle joints therein.

Lower extremity											
Wrist & Hand	Buttock	Thigh	Knee joint	Leg	Ankle	Foot	Abdomen	Back	Chest	External genital	Total
3	1	3	9	15	59	17	..	.	..	..	107
6	1	7	10	24	150	22	..	..	..	1	221
1	..	1	1	4	28	4	..	..	..	..	39
2	..	10	3	25	127	4	..	..	..	..	171

TABLE No. V.

Age Incidence.

Serial No.	Names of villages	Taluq	Under 1 year		1 to 5		6 to 10		11 to 20		21 to 30		31 to 40		41 to 50		51 to 60		Over 60		Total	
			M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M	F.
1	Tup Borgaon	Alland	..		4	..	6	6	29	17	16	10	4	4	8	2	1	.	.	..	68	39
2	Salgar	do	..	..	3	2	12	8	64	44	36	16	14	7	5	1	5	4	..	..	139	82
3	Kunsalgi	do	.	.	..	.	1	.	7	6	7	3	7	3	2	.	3	..	.	..	27	12
4	Bolegaon	do	..	..	2	6	11	4	68	22	19	9	11	8	4	5	2	..	..	..	117	54

Table V shows that persons between 11 and 20 are more susceptible to infection than persons of ages preceding or succeeding this limit. Persons over 60 years rarely suffer from the disease. Children below 1 year are free from the attack.

Cases of guinea-worm reach their maximum in the summer months—March to May—(Ardibehisht to Thir) becoming gradually less till about September (Aban). This feature is in conformity with the life history of the cyclops which usually haunt the bottom of the well, and therefore during months other than summer, when the wells are almost full of water, chances of getting the cyclops into the pot of water that is drawn from the well are very remote; conversely, during summer when the water-level in the wells falls to their minimum, the possibilities of infection are not only reversed but highly increased. The larvae of the guinea-worm, after it enters the human system, can lie dormant for a period of more or less eleven months after which time it may present itself on the surface of the body, usually prompted by some instinct on the lower extremities from where the chances of further infection are simplified, as that part of the body is almost the first to come into contact with puddles, pools and waters other than the protected draw-wells.

In this connection a few relevant extracts from a Booklet* on 'Some Epidemiological Factors of Guinea-worm Disease as noticed in a Recent Survey of the Osmanabad District' by Dr. S. Raghavender Rao, L.M.S. (Hyd.), D.T.M., D.P.H., D.Sc. (Cal.), H.E.H. the Nizam's Medical and Public Health Department, Hyderabad-Deccan, may here be quoted which go to support the above conclusions.

> "In every one of the taluqs, villages to be surveyed were selected in such a manner as to form a fair sample of the conditions prevailing in that taluk regarding social, environmental and physical characteristics. Ninety-one villages were selected in this manner and their distribution according to taluks was as follows:

Tuljapur Taluk	..	23	Villages.
Parenda do	..	23	do
Kallam do	..	23	do
Latur do	..	9	do
Osmanabad do	..	13	do

*Reprinted from the Journal of the Indian Medical Association. Vol. XI, No. II, August 1942.

" A house to house visit was made in each village surveyed and the names of persons who suffered from guinea-worm disease during the year were noted. The following information was collected regarding each such person: (*i*) name, (*ii*) age, (*iii*) sex, (*iv*) caste, (*v*) occupation, (*vi*) pertaining to the present attack: (*a*) month in which symptoms first appeared, (*b*) situation of the worm or worms, (*c*) number of worms, (*vii*) pertaining to the previous attack: (*a*) year in which the first attack took place, (*b*) total number of attacks so far, (*viii*) years of residence in the village, (*ix*) source of drinking water.

" The wells of the villages were examined systematically to find out any cyclops present in them. Where cyclops were abundant, this was an easy matter. Where they were scanty in number, straining of a large quantity of water through a thin piece of muslin and then washing the debris over the cloth into a glass dish enabled these copepods to be detected without much trouble. The condition of the wells and their nature (step-wells or draw-wells) and any sources of pollution were noted.

" Disinfection of all wells infected with cyclops was carried out with lime (50 grains of slaked lime per gallon of water). The results of disinfection were noted next day. Whenever there was a chance of revisiting the village the results were noted at frequent intervals of a week in some cases.

Incidence of guinea-worm disease in Osmanabad district.

" The annual incidence of the guinea-worm disease in the district as a whole was found to be 28.9 per mille. The highest incidence was found to be in Parenda taluk (42.3 per mille) and the lowest in Latur taluk (11.8 per mille). In the following list all the taluks of the district are arranged in the order of the severity of infection. See also the accompanying map.

1.	Parenda	..	42.3 per mille.
2.	Tuljapur	..	39.5 do
3.	Osmanabad	..	17.9 do
4.	Kallam	..	12.4 do
5.	Latur	..	11.8 do

To face p. 103.

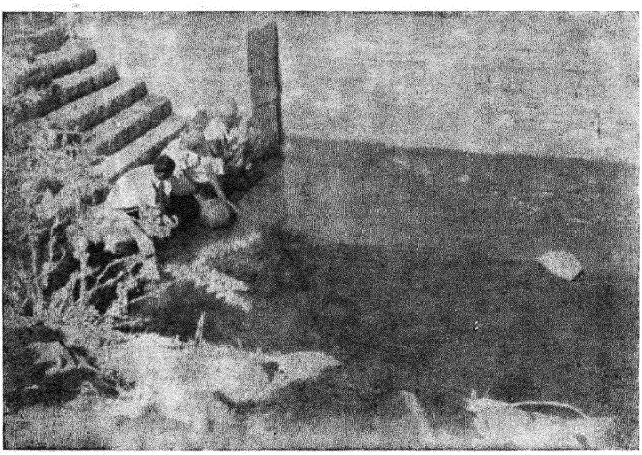


PHOTO PLATE NO. 3. *An old step well forming both a breeding centre and an endemic source of infection of guinea-worm.*

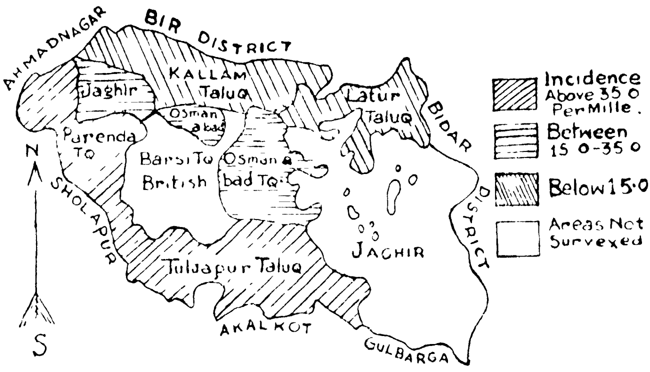


FIG. 13. *A Map showing the incidence of guinea-worm disease in different taluks of the Osmanabad district.*

"In some of the villages surveyed, the incidence of the disease was much higher than the average incidence for the taluk concerned. The following is the list of the villages surveyed where the incidence was more than 100 per mille.

"Table showing villages with incidence of guinea-worm disease more than 100 per mille.

Village	Taluk	Population	Incidence per mille
Asi	Parenda ..	700	155·7
Badgaon	Osmanabad ..	662	149·5
Tuljapur (Khurd) ..	Tuljapur ..	527	117.6
Bijanwadi	Tuljapur ..	570	117·5
Shelgaon	Parenda ..	501	111.7
Kolpa	Latur ..	382	102.1

"All these are small villages with only a single step-well supplying drinking water for the entire village.

"The incidence is rather low in the villages along the banks of the rivers and rivulets and having no other source of drinking-water supply. In the few cases found in such places infection could always be traced to some of the step-wells in the neighbouring villages, which the people frequent for the sake of fairs and festivals or weekly markets. Similarly, in villages with fairly good draw-wells without any cyclops in them, source of infection in all guinea-worm cases

found could be easily traced to some of the surrounding villages where the infection was more or less endemic.

" Details about the incidence of the disease in all taluks surveyed are given in Table.

Age Incidence

" No cases were found in children under the age of one year. The highest incidence was found in persons in the age group 11 to 20. Persons between the ages of 11 and 30 accounted for more than 50 per cent. of the total cases. The disease thus appears to be more common during active adult life. Lower incidence in children up to the age of 10 cannot be satisfactorily accounted for by any of the facts known about the disease at present. Charts A and B show that the variation in the incidence of the disease in the later age groups is only apparent and not real. It only follows the general age distribution of the population in Osmanabad district.

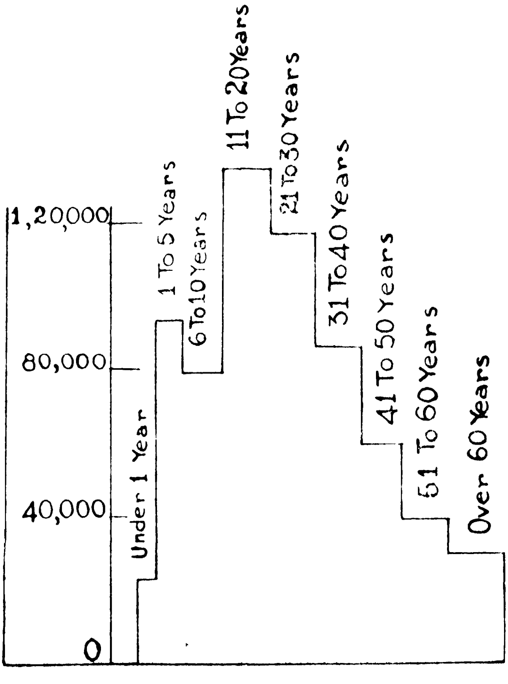


FIG. 14. *Chart showing age distribution of the population of Osmanabad district as per 1931 census.*

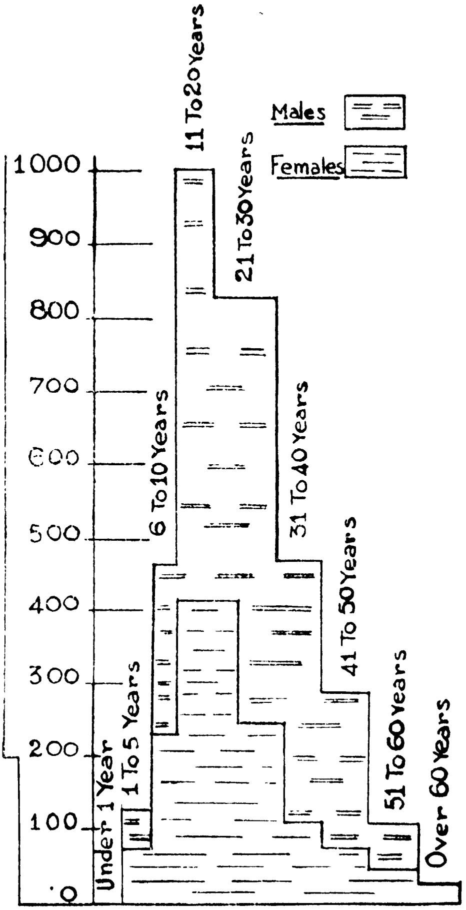


FIG. 15. *Chart showing age incidence of guinea-worm disease in Osmanabad district. Total cases investigated,* 3,129.

Table showing incidence of guinea-worm disease in the villages surveyed in Osmanabad District.

Taluk	Males			Females			Total		
	Population	Guinea-worm patients	Incidence per mille	Population	Guinea-worm patients	Incidence per mille	Population	Guinea-worm patients	Incidence per mille
Tuljapur ..	15,371	731	47.6	14,176	435	30.7	29,547	1,166	39.5
Parenda ..	8,575	500	58.4	8,489	222	27.3	17,064	722	42.3
Kallam ..	13,766	273	17.2	12,755	91	7.1	26,521	328	12.4
Latur ..	19,421	265	13.6	16,840	164	9.7	36,261	429	11.8
Osmanabad	13,951	323	23.2	13,013	161	12.4	26,964	494	17.9
Total ..	71,084	2,056	28.9	65,273	1,073	16.4	1,36,357	3,129	22.9

Sex Incidence.

"Out of a total of 3,129 cases investigated, 2,056 were males and 1,073 females, an incidence per mille of 28.4 and 16.9 respectively. This disparity is greater in villages where the infection is imported from the other villages than in the villages where the infection is indigenous. Men run a greater risk of exposure to infection on account of their going from village to village on business or pleasure. But this disparity being still present, though to a lesser extent, in villages with endemic infection one can only conclude that women are a little less liable to this disease than men. Once they have the disease both sexes suffer equally.

[*Statement*]

Table showing the incidence of the disease per mille among males and females in villages where the infection is indigenous as compared to those where infection is chiefly imported.

Village	Infection indigenous or imported	Incidence of guinea-worm disease per mille	
		Men	Women
Tuljapur	Indigenous	102	73
Bijanwadi ..	do ..	108	128
Asu	do ..	187	121
Shelgaon	do ..	170	100
Kolpa	do ..	125	77
Latur	do ..	8	5
Badgaon	do ..	154	145
Tammalwadi ..	Imported ..	15	2
Khasapuri	do ..	46	..
Ida	do	34	6
Wasi	do ..	19	5
Kallam	do ..	8	2
Murud Akola ..	do ..	14	4
Ratnapur	do	21	2

"One attack of the disease does not appear to produce any immunity from subsequent attacks. In fact, the person apparently becomes more susceptible to the disease than the one who never suffered from it. Out of a total of 3,129 cases investigated, in 2,090 or nearly 67 per cent. of cases, there was more than one attack of the disease. In 388 cases there were more than 10 attacks in the same individual in as many or more years. The highest number of attacks suffered by any individual, recorded during the present investigation was 50.

" Out of 3,129 cases investigated, in 2,086 instances there were only a single worm; in 650 cases two worms; in 193 cases three worms; in 85 cases four worms; and in 115 cases there were more than four worms in each case. Cases were not found wanting in which as many as 15 to 20 worms were found in a single case, in different situations.

Location of the worm in the body.

" In a large majority of cases these nematodes were found in the lower extremity of the patients and in them again a large number round about the ankle joints. The next most favourable situation was the leg, while in not a few cases the feet were also found to be involved. In cases where multiple worms were found, the thigh was also found to be affected, while it was rare to see the worm emerge in this situation in cases with a single worm. The knee-joint was the place most dreaded by the patient for the worm to appear. In this situation, it is difficult for the worm to be extracted and the slightest sepsis means an ankylosed knee—a great handicap for a person who has to earn his livelihood by hard manual labour. In the upper extremity the forearm and the wrist were the common situations affected. In the trunk the majority of the worms appeared on the abdomen while a few made their presence known on the back and the chest. In a small number of cases guinea-worms were found in the external genitals both in males and females. Table below gives the details of the results of investigation in this respect.

The total number of wells examined was 434. Of these 145 were step-wells and the rest draw-wells. Cyclops were found in 158 wells (mostly step-wells). The total number of wells disinfected was 183.25 of these were such that, though no cyclops were found in them at the time of examination, cases of guinea-worm disease were seen in their neighbourhood without any other obvious source of infection.

To face p. 108.

PHOTO PLATE NO. 4. *A boy of tender age having had an attack of Guinea-worm resulted in an ankylosed joint.*

PHOTO PLATE NO. 5.—*A group of men in a village who are victims of guinea-worm ravages. The disease when appearing in joints usually results in ankylosis. These men being agriculturists are thus seriously handicapped in their pursuits.*

Table showing number of previous attacks in cases of guinea-worm disease investigated in different taluks in Osmanabad district.

Taluk	Cases without any previous attack	Cases with one previous attack	Cases with two previous attacks	Cases with 3 to 10 previous attacks	Cases with more than 10 attacks
Tuljapur	266	174	119	421	186
Parenda . ..	194	108	73	226	121
Kallam . ..	113	49	33	88	45
Latur .	237	89	42	55	6
Osmanabad .	229	84	45	96	30
Total ..	1,039	504	312	886	388

Table showing number of worms in individual guinea-worm cases investigated in different taluks in Osmanabad district.

Taluk	Cases with 1 worm	Cases with 2 worms	Cases with 3 worms	Cases with 4 worms	Cases with more than 4 worms	Total number of cases investigated
Tuljapur ..	736	240	91	50	49	1,116
Parenda ..	460	173	41	15	33	722
Kallam ..	249	58	12	5	4	328
Latur ..	294	89	25	9	12	429
Osmanabad ..	347	90	24	6	17	484
Total ..	2,086	650	193	85	115	3,129

Table showing the situation of the guinea-worm in cases examined during the survey in different taluks of Osmanabad district.

Taluk	No of villages	Upper extremity: Axilla & shoulder	Upper extremity: Arm	Upper extremity: Elbow	Upper extremity: Fore-arm	Upper extremity: Hand & wrist	Lower extremity: Hips & groins	Lower extremity: Thigh	Lower extremity: Knee	Lower extremity: Leg	Lower extremity: Ankle	Lower extremity: Foot	Trunk: Abdomen	Trunk: Chest	Trunk: Back	Trunk: Genitals	Trunk: Other sites	Total
Tuljapur ..	23	..	6	..	32	35	27	150	138	454	536	276	15	9	1	13	3	1,695
Parenda ..	23	..	2	1	42	22	7	105	123	254	456	124	10	3	2	5	2	1,158
Kallam ..	23	..	..	1	8	6	3	41	25	120	185	35	2	..	..	2		428
Latur ..	9	..	1	..	5	19	20	57	53	128	229	117	8	..	1	13	1	652
Osmanabad	13	2	..	..	5	10	9	59	50	135	321	109	5	1	1	5	1	713
Total	82	2	9	2	92	92	66	412	389	1,091	1,727	661	40	13	5	38	7	4,646

"Disinfection of wells was carried out according to the standing instructions of the Public Health Department by treating them with lime at the rate of 50 grains per gallon of water in the well. Lime was either not available at all or it was of a poor quality in all the taluks except Latur. Consequently for Osmanabad and Tuljapur taluks it was purchased from Sholapur and for Kallam and Parenda taluks from Barsi town.

"Out of 183 wells disinfected, in six of them results were noted 24 hours, one week and one month after disinfection. In 24 wells results could only be noted once after 24 hours and for the second time after a week. In 99 wells the results were available for 24 hours only. The remaining wells (54 in number) were only disinfected with the required quantity of lime; there was no chance of examining them as the camp had to be shifted from the neighbourhood on the same day.

"In all these wells examined, cyclops were scarce after six hours and disappeared entirely after 24 hours. Cyclops reappeared after one week in one of the 24 wells examined. In six wells examined after one month cyclops had reappeared in the same numbers as before disinfection. In only one of these there was no trace of cyclops, but this step-well concerned was a small one and at the same time of the last examination was overflowing into a neighbouring rivulet owing to heavy rains.

Table showing the number of wells disinfected and examined for cyclops in different taluks in Osmanabad district.

Taluks	Wells examined: Step wells	Wells examined: Draw wells	Wells examined: Total	Wells found to contain cyclops & disinfected	Wells not found to contain cyclops but still suspicious & hence disinfected
Tuljapur .	59	60	119	50	8
Parenda .	31	38	69	43	13
Kallam ..	19	95	114	27	3
Latur ..	14	37	51	15	1
Osmanabad ..	22	59	81	23	..
Total ..	145	289	434	158	25

Experimental work

"Owing to the unsatisfactory condition of the results obtained from the disinfection of wells with lime (as cyclops invariably reappeared after a variable interval), and the varying qualities of lime obtained in the local markets, a small series of experiments was carried out at the Civil Hospital, Latur, by the author, with the local well water which abounded in cyclops and with three different varieties of lime available in the local markets. Details of the experiments are given in Table below:

[*Statement*.

Table showing results of experiments carried out at Latur to find out the best variety of lime available locally for disinfecting wells for cyclops.

Date	Well water used	Quantity of water	Approx. No of cyclops present	Quality of lime used	Strength of lime	After 3 hrs	After 6 hrs	After 12 hrs	After 24 hrs.	Remarks
10-7-37 ..	Papanas well.	3,000 C.C.	500	1	1 . 2,3000	F L.C	N L.C	N L C.	N L C	Water clarified within 6 hours
do .	do	do	500	2	do	C A	C A	do	do	Water still white after 24 hours
do ..	do	do	500	3	do	do	do	C.A.	C A.	do
do .	do	do	500			do	do	do	do	Control
11-7-37	do	do	500	1	do	F.L C	N L.C	N L.C	N L.C	Water clarified within 6 hours.
do .	do	do	500	2	do	C.A.	C A.	do	do	Water still white after 24 hours.
do .	do	do	500	3	do	do	do	C A.	C A.	do
do .	do	do	500			do	do	do	do	Control.
12 7-37 .	do	do	500	1	1 : 4,600	F L.C.	N.L.C.	N L.C	N.L C.	
do ..	do	do	500	2	do	do	F L C	do	do	
do	do	do	500	.		L.C.	L.C.	C.A.	C.A.	Control

1—Surti lime. 2—Lime prepared from Shahbad stones. 3—Lime prepared from country stones C.A Cyclops alive.
N. L. C.—No live Cyclops. F. L. C.—Few live Cyclops. L. Cy.—Live cyclops.

"The three different varieties of lime in these experiments were :—

1. *Surti Lime* (quick-lime). This is probably prepared from shells; is imported from outside and comes packed in tins suitable for storing and transportation.

2. *Lime Prepared from Shahbad Stones.* This is available locally in several places. Both slaked and unslaked forms can be had. Unslaked form is difficult to carry from place to place particularly during rainy season.

3. *Lime Prepared from Country Stones and Pebbles*: Available in small quantities in several places in the district.

"As far as the present experiments are concerned the last variety (lime made from country stones) had proved comparatively useless. The first variety (Surti lime) is the best. Lime from Shahbad stones is fairly good and throughout this survey this variety was used for the disinfection of almost all the wells.

Summary

"A guinea-worm disease survey of the Osmanabad district in H.E.H. the Nizam's Dominions was carried out from the middle of April to middle of July, 1937.

"Incidence of guinea-worm disease for the whole district was found to be 28.9 per mille. For some of the taluks it was as much as 42.3 per mille. In some of the villages surveyed it was as high as 155 per mille.

"Men were found to be slightly more susceptible than women. Young adults were attacked more than persons in other age groups. Children under the age of one year were found to be free.

"In nearly 67 per cent of the cases investigated persons suffered from more than one attack. The highest number of attacks recorded during the present investigation in a single individual, was 50.

"Data were collected and tabulated with regard to such factors as the number of worms in a case and the situations in the body where the worms usually emerged.

"Some experimental work was carried out to find out the relative value of different varieties of lime found locally as disinfectants of wells against cyclops.

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PHOTO PLATE NO. 6. *In villages situated on nala banks the only contaminated source of water supply in summer is from ' Chesmas ' in the bed of the nala. During floods the villagers drinking the muddy water become victims to water-borne diseases particularly Cholera.*

" Suggestions have been made with regard to the improvement of wells (conversion of step-wells into draw-wells) as a permanent measure of protection. Construction of draw wells of standard design have been recommended. Treatment of wells by village officials with lime at regular monthly intervals, particularly from the months of August to April, has been suggested as a temporary measure till the adoption of permanent measures."*

During the early stages, the provision of protected draw wells in villages along perennial nalas and rivers was not only seriously considered, but as the works progressed it was noticed that, soon after the first few freshets which carried all the surface filth and contamination, the inhabitants of such villages, by drinking these waters, were periodically becoming victims to water-borne diseases, particularly cholera, which besides taking heavy toll of lives, put the government to huge expense of remedial and ameliorative work. In order to offset this recurring expense, the government resolved that this department should provide wells in such villages also ; and it is a matter of gratification to see that the provision of wells in these villages has almost rid them of these pestilential diseases.

*Read at the Scientific Section of the XVIII All-India Medical Conference, Hyderabad-Deccan, December 1941.

PART III

ORGANISATION & TECHNIQUE

CHAPTER I

The Well Sinking Department, sponsored by H.E.H. the Nizam's Government is a unique and vast organisation, and is not only investigating the conditions of water supply in villages where the rainfall per annum is 25 inches and below but is engaged primarily in the sinking of protected perennial wells at appropriate places in the villages, entailing an annual expenditure of eight lakhs of rupees for the present, with the utilisation of much labour, technical outfits and the consumption of large quantities of materials like cement, explosives etc.; the co-ordinate system adopted to facilitate the efficient working and the control as a whole may here be enumerated.

Areas on the basis of 25 inches and below of annual rainfall, are arrived at by drawing the hydrographic lines as shown on the superimposed transparent sheet over the geological map of the State, and are distributed according to taluqs and districts, and at suitable centres the headquarters of the department is stationed, and the work started in the areas in charge of sub-divisional and sectional officers after investigation and final results, as approved by the government. The Famine areas arrived on this basis are:

I. The whole of Raichur district.

II. The three Sarf-i-Khas Mubarak taluqs of Shorapur, Shahpur and Andola.

III. Parts of Diwani taluqs of Yadgiri and Gulbarga of Gulbarga district.

IV. Parenda and Tuljapur taluqs of Osmanabad district.

V. Ashti, Patoda and Gevrai taluqs of Bhir district.

VI. Ambad, Paithan, Vaizapur and Gangapur taluqs of Aurangabad district.

VII. Nilanga of Bidar district.

VIII. Makthal, Mahboobnagar, Nagarkurnul, Kalvakurthi, Amrabad taluqs, and Wanparthy Samasthan of Mahboobnagar district.

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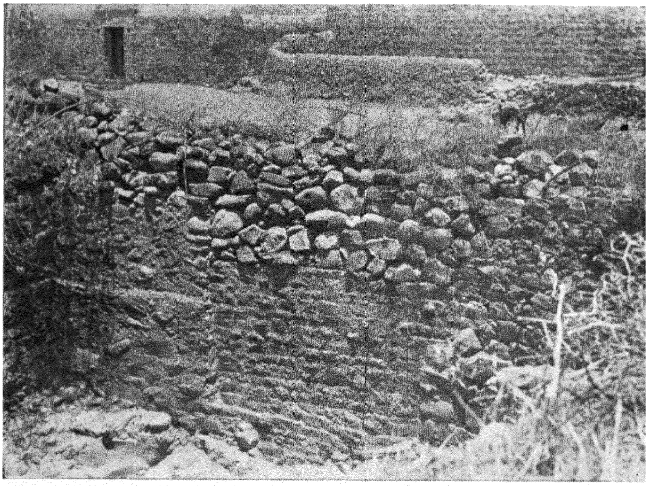


PHOTO PLATE NO. 7.—*An old step well with loose unstable steining, which besides proving dangerous, permits the filthy water from the surroundings getting into the well and contaminating the source of water supply.*

IX. Deverkonda, Bhongir, part of Nalgonda and Miriyalguda taluqs of Nalgonda district.

Block system.

The works which were then let out to contractors at random in the beginning stages involving expense and trouble and in some cases, in the abandonment of work due to segregation, were later on centralised by Block System, numbered serially for each taluq, comprising places between the adjacent 5 minutes Longitudes and Latitudes, forming more or less an area of 30 square miles.

Details of preliminary work.

Before any work can be started, it is essential to know the details regarding the villages in which wells are to be given, or if adequate water supply exists, to remodel those wells to form protected water supply, together with the total number of wells that are to be provided in a taluq or remodelled or steps blocked or sterilised. In order to arrive at the information a preliminary investigation of the famine zones village by village in each taluq is undertaken, and all the available data of the existing seasonal, perennial as well as old abandoned wells, their logs, depths, waterlevels, sizes, nature, whether step or draw wells, with or without steining, with or without parapet, their sources of water supply, whether sweet, brackish or saline and the possibilities of contamination, whether infected with guinea-worm, etc., together with the population of different sects of the village, and the available statement of epidemics, particularly of guinea-worm patients, both existing and past cases, as gathered from the village officials are collected and recorded. If the water supply is found adequate and its source free from contamination then no action is taken to provide wells in the village. But in villages where the water supply is not only meagre, but is highly contaminated due to the existence of cess pools, manure pits, accumulation of filth or herding of cattle within the village precincts, thus fouling the ground for centuries past, new well sites are chosen far away from the influence of any such infection. Judicious care is bestowed in the selection of well sites as stated in the foregoing parts, and in order to avoid legal complications and to safeguard the interest of the pattadars as well as the villagers, well sites are usually selected in government lands provided the physiographic and geologic conditions are satisfactory; otherwise if sites fall within cultivable lands they are so chosen as to cause minimum of inconvenience to the owner who is duly compensated. Usually wet lands are avoided for well sites.

If, for unavoidable circumstances, well sites are chosen in lands where crops are standing, works are not started until the crops are either removed or the pattadars give their written consent not to claim compensation on the crops ; in the latter case the crops are removed by the department and works started. If pattadars are unwilling to the latter proposal, panchnamas are held and the estimated cost of the crops is arrived at, and after the compensations are paid works are started. In order to avoid legal complications a statement in the form below is obtained.

Name of Village	Survey number	Name of Pattadar	Number and nature of wells	Area of land required including 6' wide foot-path if need be	Whether the pattadar is willing to part with his land		Whether crop is standing or not
					With compensation	Without compensation	
1	2	3	4	5	6		7

Usually pattadars who appreciate the ameliorative uplift work conducted by the government do not create any impediments but in cases where pattadars are sometimes obstinate they are then explained the advantages that accrue to the people at large, and the small sacrifice they could afford in order to improve their own condition towards which the government is so generously spending money. If all these endeavours fail, then the usual procedure is adopted to acquire the land and the revenue authorities are requested to proportionately reduce the land tax, to the extent of the portion of the land acquired for well sinking.

The extent of land thus acquired in cases of various type designs of wells is as follows :

1. 4 feet hexagonal and pentagonal wells, including cattle trough ; 50×50 feet=0.057 acres.

2. 7 feet hexagonal and pentagonal wells including cattle trough : 60×60 feet=0.082 acres.

3. Approach track of 6 feet wide from the nearest track.

During the course of the work, the geological informations and sequence of beds of Deccan traps are worked out from natural sections or available cuttings in order to compare with the logs of wells obtained. In some cases the want of such natural sections or cuttings, combined with extensive soil cover masking the underlying rocks, so handicaps as to entirely make us depend upon the well logs available in the area. A method of arriving at a reliable sequence is from

If crop is standing approximate compensation as per panchnama	WHETHER THE PATTADAR IS WILLING TO ALLOW HIS CROP BEING CUT		ACCEPTANCE AND SIGNATURE OR THUMB IMPRESSION OF THE PATTADAR		Verification of Patel and Patwari	REMARKS BY THE WELL SINKING DEPARTMENT IF PATTADAR IS UNWILLING	
	With compensation	Without compensation	Regarding land	Regarding crop		Regarding land	Regarding crop
8	9		10		11	12	

the correlation of the records of core-drilling at several places when they are available.

As regards the number of wells to be provided in each village, a tentative basis of one well per 500 population is followed. As the situation warrants, one or more well sites are given at each village for the general public.

The depressed classes who, because of their poverty and obvious social position, do not enjoy the same privileges cannot afford the expense of sinking wells. During the rain and after, they can get water from some distant secluded pits in the nalas, but have to finally fall back upon the doles of the so-called higher caste people for drinking water for which sometimes they have to wait for hours; the question of provision of protected wells to these classes, though most urgent and important, grew perplexing and difficult in view of their subsects *e.g. Dhers, Mongs, Chambars, Mochis, etc.*, not

jointly taking water from the common well provided for them. In the beginning stages therefore, more than one well was constructed in the Raichur district if the population of the different sub-sects of the '*Harijans*' so warranted them. In cases where their number was small, it was considered economical to construct only one well with a partition wall in the centre which sealed off the water of each half, allotting each of the halves to the Dhers and Mongs. The latter availed the use of such wells, but the former refused, because they considered themselves superior to the other sub-sects. The construction of such combined wells was therefore given up entirely and only one well is now being provided in its place and assigned to the mongs, who have no objection to the use of the same well by the other subsects.

Paigahs, Jaghirs and Inam lands

As the State is studded with Paigahs, Jaghirs and Inam lands some of which fall within famine zones, in order to create similar beneficial conditions by the provision of protected draw wells by the concerned authorities, the government have granted long term loans to them at a nominal rate of interest of two per cent per annum and the capital rocovered in instalments.

These details of investigation are submitted to the Special Officer-in-Charge Well Sinking Department, who decides the matter village by village on their merits or demerits, and finally datas are arrived at for that taluq, giving the total number of new wells to be sunk, old wells to be remodelled, stepwells to be blocked or wells to be sterilised. These are forwarded to the Taluqdar of the district for information, suggestions and countersignature and then submitted to the government for sanction. As soon as sanction is received tenders are called for and the works are let out block by block to the approved contractors on agreement bonds signed by them under the following conditions:—

W. S. D. FORM No. 60.

H.E.H. the Nizam's Well Sinking Department: Notice Inviting Tenders for Works in..................District.

1. Tenders are hereby invited for sinking, lining with reinforced cement concrete, sterilising, blocking and filling of about..........................wells.

2. Documents consisting of the detailed plans, specifications, schedule of rates, approximate quantities of various classes of work to be done and the conditions of the contracts

to be complied with by the person whose tender may be accepted, can be seen during office hours except on public holidays at the Well Sinking Department offices.

3. Tenders which should not contain any correction and should be in sealed covers will be received by the sub-divisional officer, Well Sinking Department............ up to...................on the.................. and will be opened by him in his office on the same day at...... ....in the presence of such of the contractors as may choose to be present.

Contractors who are not working at present in this department should submit copies of testimonials of work done by them elsewhere and which should be from an officer not below the rank of an Executive Engineer, for previous work done by them elsewhere.

4. The tenders are to be in prescribed form which can be obtained for Re. 0-8-0 a form, from any of the Well Sinking offices.

5. The Contractor should quote the percentage below the current schedule of rates............district a copy of which can be obtained for Re. 0-8-0 from any of the Well Sinking offices or quote their own rates.

The district P.W. D. schedule of rates for items not provided in the current schedule of rates.

6. The tenderer should specify :

i. the number of wells he would undertake.

ii. the number of wells with pulleys that he would be able to complete in......................failing which penalty of Rs. 10 per each well not completed shall be levied.

1. *iii.* the total amount that he will spend in........ at the progressive rate of expenditure that will be fixed by the department failing which penalty of 5 per cent of the unspent amount will be levied.

It must be understood that the contract shall have to be completed by end of....... .. ..

Besides the penalty, the Special Officer reserves to himself the right to cancel the contract without notice if the contractor fails to keep up to his agreement either to show proportionate progress on expenditure or complete works as laid down above.

It should be understood that the tendered rates will be applicable and binding even if the number of works now allotted is reduced or increased during execution of work.

7. Earnest money at the rate of Rs. 25 per work should be deposited with any treasury, where the department has account and the certified copy of the chalan should be attached to the tender.

The earnest money of the contractor whose tender is accepted will be forfeited to the government, if he fails to start or complete the work within the time specified in the agreement bond.

8. The earnest money will be released on the expiry of one year from the final settlement of work. During this period whatever defects may arise in the work, will have to be rectified by the contractor at his own cost, failing which the department will be at liberty to rectify the defects at the expense of the contractor and the cost recovered from the earnest money and other dues to the contractor.

9. The acceptance of a tender will rest with the Special Officer who does not bind himself to accept the lowest tender and reserves to himself the right to reject any or all of the tenders received, without assigning any reason.

The works will be allotted by the Special Officer at his discretion.

The Special Officer does not bind himself also to let out the number of works tendered for, but reserves to himself the right to accept the tender either in toto or with modifications by reducing or increasing the number of works tendered for, without assigning any reason. It is, however, to be understood that the amount of contract allotted will not be less than about Rs.........................in any case.

10. Contractors will be responsible for payment of compensation according to the Workmen's Compensation Act No. 6 of 1349 F., or its modifications from time to time in case of the accidents to the workmen in their employment.

11. Cement, reinforcement, pulleys, number plates, iron steps etc., will be supplied by the department.

Moulds will be supplied by the department on monthly rent.

Explosives will be supplied by the department on cash sale under the conditions of para 8 of the agreement bond.

12. Standing orders of the department already issued and those that may be issued in future, will be binding on the contractors.

SUB-DIVISIONAL OFFICER,
Well Sinking Department.

No. Date :

Copy forwarded to..................for information.

SUB-DIVISIONAL OFFICER,
Well Sinking Department.

W.S.D. Form No. 45.

H.E.H. THE NIZAM'S WELL SINKING DEPARTMENT

No.

Date..........

To

The Special Officer-in-Charge,

Well Sinking Department, ...

SIR,

Under the conditions laid down in the notice inviting tenders for sinking and lining of wells with reinforced cement concrete and remodelling into draw wells, blocking steps, sterilising and filling of old wells in the................ taluq of the.......................district I hereby beg to tender for......................works and.......... per cent below the current schedule of rates of Well Sinking Department. A sum of Rs......... towards earnest money is herewith deposited therefor, to be dealt with in the manner specified in the aforesaid notice.

I hereby declare to abide myself in all respects by the conditions of the agreement bond and the standing orders of the department.

I beg to remain,
Sir,
Your most obedient servant,

Date..........

Address :

....

....

....

Piece Contract Agreement Bond for Works under Well Sinking Department

H.E.H. THE NIZAM'S GOVERNMENT

I..........................son of.................
Contractor, resident of....................district ....
............agree to carry out and fully complete in......
............months from the date of mark-out, in accordance with the standard specifications and to the satisfaction of the Special Officer, Well Sinking Department, the work of the well ....at ....
Block No...................Taluq...................
District...............................

I further fully understand and agree that :

1. The work will be executed on piece work system, and government is at liberty to terminate it after giving a month's notice, in which case I shall be entitled to receive the deductions made from my bills.

2. I undertake to safeguard all government materials and tools and plant given to me. I shall pay for all the damages done to such articles, as the department may decide and maintain them during the period they are with me.

3. I agree to purchase all government materials that may have been collected so far for masonry and cement concrete works in the work let out to me.

4. The rates will be as per schedule annexed to this agreement. As regards any other items of work for which rates are not mentioned in the schedule, I shall be paid at P.W.D. district schedule of rates or at rates to be worked out by the Special Officer and as may be subsequently sanctioned by the Famine Board.

5. A deduction of ten per cent from my bills shall be made and kept as security, which shall be refunded to me in full, after the work of the well let out to me on contract has been completed in all details. If, however, I fail to complete within the stipulated time, government shall be at liberty to confiscate the amounts deducted from the bills and kept as security as mentioned above.

6. My dues on this or any other works partly or completely shall be withheld and paid to the labour, by the government, if I be found not paying the labour regularly.

7. If the work be closed by me, the last contract certificate shall be considered final and the amounts withheld shall lapse to the government.

8. Explosives of all kinds are issued to me solely for the use of my contract work under the Well Sinking Department and I fully understand that I am alone responsible for their safe custody. I will always keep the dynamites (gelignite) and detonators separate, carefully under lock and key. I fully understand that I should be guilty of a very serious breach of law, if I sell, barter, loan or otherwise dispose of explosives of any kind to a third party even though that party be a government servant or another government contractor. I agree to keep a correct daily record of all dynamite (gelignite) and the detonators used on my work specifying on that work it was employed. This account which will always be available for inspection on demand by the authorised officer of the department, will be produced by me before any new issue can be sanctioned from stores. I further agree to undergo any departmental punishment or forfeiture of any of my dues and property or both, in case of my irregularity or neglect on my part in maintaining proper accounts or for any improper use of explosives given under my charge.

9. I shall pay such hire on tools and machinery, etc., as may be fixed by the department from time to time.

10. I will be responsible for the payment of compensation according to the Workmen's Compensation Act No. 6 of 1349 F., in case of accidents to the workmen under my employment.

11. I further agree that the security deposit of Rs. 25 may be withheld for one year after the date of recording the final measurements. During the period I am responsible for all the defects arising in the well. I also undertake to rectify the defects at any cost without claiming any payment. If I fail to carry out the rectifications, the department is at liberty to get the work done through any agency at any rates and recover the cost from my dues payable to me either in this or any other well.

12. In token of my Agreement to complete the work in ....months, I hereby deposit Rs......... ....credited vide cash book folio .. ...dated....../diverted from other works vide S.O's No. ....dated..............................

which shall be refunded to me after I complete the entire work. The government shall be at liberty to confiscate this amount if I fail to start the work in a.................. time, and after that show a proportionate progress or fail to complete it.

Date.............   *Signature of contractor.*

Witnesses :
(1) ....
(2) ....

Signed on behalf of His Exalted Highness the Nizam's Government in token of agreement to the above general conditions on the..................... .day of.......... ....month 135 F.

Witness :

Signature of Sub-divisional Officer, Well Sinking Department.	*Special Officer, Well Sinking Department.*

Well Sinking (excavation) in various soils and for various depths in Osmanabad district for 100 Cu. ft.

SCHEDULE OF RATES

—		SOFT SOILS			
		New wells		Old wells	
		Dry	With pumping	Dry	With pumping
0 - 5	..	1 8 0	2 4 0	..	..
6 -10	..	2 0 0	3 0 0	2 0 0	3 0 0
11 -15	..	2 8 0	3 12 0	2 0 0	3 0 0
16 -20	..	3 0 0	4 8 0	2 0 0	3 8 0
21 -25	..	3 0 0	4 12 0	2 8 0	4 4 0
26 -30	..	3 4 0	5 4 0	2 12 0	4 12 0
31 -35	..	3 8 0	5 8 0	3 0 0	5 4 0
26 -40	..	4 0 0	6 4 0	3 8 0	5 12 0
41 -45	..	5 4 0	7 4 0	4 8 0	6 4 0
46 -50		6 4 0	8 8 0	5 12 0	6 12 0
51 -55	..	..	..	..	..
56 -60	..	..	..	..	..
61 -65	..	..	..	..	..
66 -70	..	..	..	..	..
71 -75	..	..	..	..	..
76 -80	..	..	..	..	..
81 -85	..	..	..	..	..
86 -90	..	..	..	..	..
91 -95	..	..	..	..	..
96 -125	..	..	..	..	..

SCHEDULE OF RATES

—	Hard Soils			
	New wells		Old wells	
	Dry	With pumping	Dry	With pumping
0 - 5 ..	3 0 0	4 8 0	..	..
6 - 10	4 0 0	6 0 0	4 0 0	6 0 0
11 - 15 ..	6 0 0	9 0 0	5 4 0	8 8 0
16 - 20 ..	8 0 0	13 0 0	6 4 0	11 12 0
21 - 25 ..	10 0 0	16 0 0	7 4 0	12 12 0
26 - 30 ..	13 0 0	20 0 0	7 12 0	13 4 0
31 - 35 ..	15 0 0	23 8 0	8 4 0	13 12 0
36 - 40 ..	18 0 0	26 12 0	8 12 0	14 4 0
41 - 45 ..	19 12 0	27 12 0	9 4 0	14 12 0
46 - 50 ..	21 0 0	29 12 0	10 8 0	15 8 0
51 - 55 ..	22 0 0	32 0 0	11 0 0	16 0 0
56 - 60 ..	23 0 0	33 0 0	11 8 0	16 8 0
61 - 65 ..	24 0 0	34 0 0	12 0 0	17 0 0
66 - 70 ..	25 0 0	35 0 0	12 8 0	17 8 0
71 - 75 ..	26 4 0	36 4 0	13 0 0	18 0 0
76 - 80 ..	27 4 0	37 4 0	13 8 0	18 8 0
81 - 85 ..	28 4 0	38 8 0	14 0 0	19 4 0
86 - 90 ..	29 4 0	39 8 0	14 8 0	19 12 0
91 - 95	30 4 0	40 8 0	15 0 0	20 4 0
96 -125 ..	31 8 0	42 12 0	15 12 0	21 4 0

SCHEDULE OF RATES

—	SOFT ROCKS											
	NEW WELLS						OLD WELLS					
	Dry			With pumping			Dry			With pumping		
0 - 5 ..	3	8	0	6	0	0	..			..		
6 - 10 ..	6	8	0	9	0	0	5	12	0	8	8	0
11 -15 ..	9	8	0	13	0	0	8	12	0	12	12	0
16 - 20 ..	12	0	0	18	0	0	10	8	0	16	0	0
21 - 25 ..	15	12	0	22	4	0	13	8	0	19	4	0
26 - 30 ..	18	12	0	26	12	0	14	8	0	20	4	0
31 - 35 ..	21	8	0	29	12	0	15	12	0	21	4	0
36 - 40 ..	24	0	0	32	0	0	15	12	0	22	4	0
41 - 45 ..	26	4	0	34	0	0	16	12	0	24	4	0
46 - 50 ..	28	4	0	36	4	0	17	12	0	24	8	0
51 - 55 .	31	8	0	39	8	0	19	12	0	27	12	0
56 - 60 ..	33	8	0	41	8	0	21	0	0	28	12	0
61 - 65 ..	35	8	0	42	12	0	22	0	0	29	12	0
66 - 70 ..	37	12	0	43	12	0	23	0	0	31	0	0
71 - 75 ..	37	12	0	44	12	0	24	0	0	32	0	0
76 - 80 ..	38	12	0	46	0	0	25	0	0	34	0	0
81 - 85 ..	39	12	0	48	0	0	26	12	0	36	4	0
86 - 90 ..	42	0	0	51	4	0	27	4	0	38	8	0
91 - 95	44	0	0	53	8	0	29	4	0	40	8	0
96 -125 ..	47	4	0	58	12	0	31	8	0	42	12	0

SCHEDULE OF RATES

—	HARD ROCKS			
	New wells		Old wells	
	Dry	With pumping	Dry	With pumping
0 - 5 ..	15 0 0	22 0 0	..	..
6 - 10 ..	18 0 0	26 12 0	18 0 0	26 12 0
11 - 15 ..	21 0 0	29 12 0	21 0 0	29 12 0
16 - 20 ..	24 0 0	33 0 0	24 0 0	33 0 0
21 - 25 ..	27 8 0	38 8 0	27 8 0	36 4 0
26 - 30 ..	31 0 0	42 12 0	31 0 0	39 8 0
31 - 35 ..	35 0 0	47 0 0	34 8 0	43 12 0
36 - 40 ..	40 0 0	53 8 0	37 12 0	48 0 0
41 - 45 ..	45 0 0	58 12 0	40 12 0	52 4 0
46 - 50 ..	50 0 0	64 0 0	44 0 0	58 12 0
51 - 55 ..	55 0 0	70 8 0	47 4 0	63 0 0
56 - 60 ..	60 0 0	77 0 0	50 4 0	67 4 0
61 - 65 ..	68 4 0	83 4 0	52 8 0	71 8 0
66 - 70 ..	73 8 0	90 12 0	55 8 0	75 12 0
71 - 75 ..	78 12 0	101 8 0	58 12 0	80 4 0
76 - 80 ..	84 0 0	112 4 0	61 12 0	85 8 0
81 - 85 ..	89 4 0	123 0 0	65 0 0	90 12 0
86 - 90 ..	94 8 0	133 12 0	69 4 0	96 4 0
91 - 95 ..	99 12 0	144 4 0	73 8 0	101 8 0
96 - 125 ..	105 0 0	155 0 0	78 12 0	112 4 0

Well Sinking (excavation) in various soils and for various depths per 100 Cu. ft. Gulbarga district and Yadgiri taluq

SCHEDULE OF RATES.

—	SOFT SOILS			
	New wells		Old wells	
	Dry	With pumping	Dry	With pumping
0 - 5 ..	1 8 0	2 4 0	..	..
6 - 10 ..	2 0 0	3 0 0	2 0 0	3 0 0
11 - 15 ..	2 8 0	3 12 0	2 0 0	3 0 0
16 - 20 ..	3 0 0	4 8 0	2 0 0	3 8 0
21 - 25 ..	3 0 0	4 8 0	2 8 0	4 0 0
26 - 30 ..	3 4 0	5 0 0	2 12 0	4 8 0
31 - 35 ..	3 8 0	5 8 0	3 0 0	5 0 0
36 - 40 ..	4 0 0	6 0 0	3 8 0	5 8 0
41 - 45 ..	5 0 0	7 0 0	4 8 0	6 0 0
46 - 50 ..	6 0 0	8 0 0	5 8 0	6 8 0
51 - 55 ..	..	..	..	..
56 - 60 ..	..	..	..	..
61 - 65 ..	..	..	..	..
66 - 70 ..	..	..	..	.
71 - 75 ..	..	..	..	..
76 - 80 ..	..	..	..	..
81 - 85 ..	..	..	..	..
86 - 90 ..	..	..	..	..
91 - 95 ..	..	..	..	..
96 -125 ..	..	..	..	..

SCHEDULE OF RATES

—	HARD SOILS			
	NEW WELLS		OLD WELLS	
	Dry	With pumping	Dry	With pumping
0 - 5 ..	3 0 0	4 8 0	..	..
6 - 10 ..	4 0 0	6 0 0	4 0 0	6 0 0
11 - 15 ..	6 0 0	9 0 0	5 0 0	8 0 0
16 - 20 ..	8 0 0	13 0 0	6 0 0	11 0 0
21 - 25 .	10 0 0	16 0 0	7 0 0	12 0 0
26 - 30 ..	13 0 0	20 0 0	7 8 0	12 8 0
31 - 35 ..	15 0 0	22 0 0	8 0 0	13 0 0
36 - 40 ..	18 0 0	25 0 0	8 8 0	13 8 0
41 - 45 ..	19 0 0	26 0 0	9 0 0	14 0 0
46 - 50 ..	20 0 0	28 0 0	10 0 0	14 8 0
51 - 55	21 0 0	30 0 0	10 8 0	15 0 0
56 - 60 ..	22 0 0	31 0 0	11 0 0	15 8 0
61 - 65 ..	23 0 0	32 0 0	11 8 0	16 0 0
66 - 70 ..	24 0 0	33 0 0	12 0 0	16 8 0
71 - 75 ..	25 0 0	34 0 0	12 8 0	17 0 0
76 - 80 ..	26 0 0	35 0 0	13 0 0	17 8 0
81 - 85	27 0 0	36 0 0	13 8 0	18 0 0
86 - 90 ..	28 0 0	37 0 0	14 0 0	18 8 0
91 - 95 ..	29 0 0	38 0 0	14 8 0	19 0 0
96 -125 ..	30 0 0	40 0 0	15 0 0	20 0 0

SCHEDULE OF RATES

	SOFT ROCKS			
	New wells		Old wells	
	Dry	With pumping	Dry	With pumping
0 - 5 ..	3 8 0	6 0 0	..	..
6 - 10 ..	6 8 0	9 0 0	5 8 0	8 0 0
11 - 15 ..	9 8 0	13 0 0	8 8 0	12 0 0
16 - 20 ..	12 0 0	17 0 0	10 0 0	15 0 0
21 - 25 .	15 0 0	21 0 0	13 0 0	18 0 0
26 - 30 ..	18 0 0	25 0 0	14 0 0	19 0 0
31 - 35 ..	20 8 0	28 0 0	15 0 0	20 0 0
36 - 40 ..	23 0 0	30 0 0	15 0 0	21 0 0
41 - 45 ..	25 0 0	32 0 0	16 0 0	21 0 0
46 - 50 ..	27 0 0	34 0 0	17 0 0	23 0 0
51 - 55 ..	30 0 0	37 0 0	19 0 0	26 0 0
56 - 60 .	32 0 0	39 0 0	20 0 0	27 0 0
61 - 65 .	34 0 0	40 0 0	21 0 0	28 0 0
66 - 70 ..	35 0 0	41 0 0	22 0 0	29 0 0
71 - 75 .	36 0 0	42 0 0	23 0 0	30 0 0
76 - 80 ..	37 0 0	43 0 0	24 0 0	32 0 0
81 - 85 ..	38 0 0	45 0 0	25 8 0	34 0 0
86 - 90 .	40 0 0	48 0 0	26 0 0	36 0 0
91 - 95 .	42 0 0	50 0 0	28 0 0	38 0 0
96 -125 ..	45 0 0	55 0 0	30 0 0	40 0 0

SCHEDULE OF RATES.

—	Hard Rocks			
	New wells		Old wells	
	Dry	With pumping	Dry	With pumping
0 - 5 ..	15 0 0	22 0 0	..	..
6 - 10 ..	18 0 0	25 0 0	18 0 0	25 0 0
11 - 15 ..	21 0 0	28 0 0	21 0 0	28 0 0
16 - 20 ..	24 0 0	31 0 0	24 0 0	31 0 0
21 - 25 ..	27 8 0	36 0 0	27 0 0	34 0 0
26 - 30 ..	31 0 0	40 0 0	30 0 0	37 0 0
31 - 35 ..	35 0 0	44 0 0	33 0 0	41 0 0
36 - 40 ..	40 0 0	50 0 0	36 0 0	45 0 0
41 - 45 ..	45 0 0	55 0 0	39 0 0	49 0 0
46 - 50 ..	50 0 0	60 0 0	42 0 0	55 0 0
51 - 55 ..	55 0 0	66 0 0	45 0 0	59 0 0
51 - 60 ..	60 0 0	72 0 0	48 0 0	63 0
61 - 65 ..	65 0 0	78 0 0	50 0 0	67 0 0
66 - 70 ..	70 0 0	85 0 0	53 0 0	71 0 [illegible]
71 - 75 ..	75 0 0	95 0 0	56 0 0	75 0 0
76 - 80 ..	80 0 0	105 0 0	59 0 [illegible]	80 0 0
81 - 85 ..	85 0 0	115 0 0	62 0 0	85 0 0
86 - 90 ..	90 0 0	125 0 0	66 0 0	90 0 0
91 -95 ..	95 0 0	135 0 0	70 0 0	95 0 0
91 -125 ..	100 0 0	145 0 0	75 0 0	105 0 0

Well Sinking (excavation) in various soils and for various depths per 100 Cu. ft. Ashti, Patoda, Bhum Jaghir, and Afzalpur Paigah

SCHEDULE OF RATES

—	SOFT SOILS			
	New wells		Old wells	
	Dry	With pumping	Dry	With pumping
0 - 5 ..	1 8 0	2 4 0	..	..
6 - 10 ..	2 0 0	3 0 0	2 0 0	3 0 0
11 - 15 ..	2 8 0	3 12 0	2 0 0	3 0 0
16 - 20 ..	3 0 0	4 8 0	2 0 0	3 8 0
21 - 25 ..	3 0 0	4 12 0	2 8 0	4 4 0
26 - 30 ..	4 4 0	5 4 0	2 12 0	4 12 0
31 - 35 ..	3 8 0	5 8 0	3 0 0	5 4 0
36 - 40 ..	4 0 0	6 4 0	3 8 0	5 12 0
41 - 45 ..	5 4 0	7 4 0	4 8 0	6 4 0
46 - 50 ..	6 4 0	8 8 0	5 12 0	6 12 0
51 - 55 ..	..	..	..	..
56 - 60 ..	..	..	..	..
61 - 65 ..	..	..	..	..
66 - 70 ..	..	..	..	..
71 - 75 ..	..	..	..	..
76 - 80 ..	..	..	..	..
81 - 85 ..	..	..	..	..
86 - 90 ..	..	..	..	..
91 - 95 ..	..	..	..	..
86 -125 ..	..	..	..	..

SCHEDULE OF RATES

	HARD SOILS											
	New wells						Old wells					
	Dry			With pumping			Dry			With pumping		
0 - 5 ..	3	0	0	4	8	0	..			..		
6 - 10 ..	4	0	0	6	0	0	4	0	0	6	0	0
11 - 15 ..	6	0	0	9	0	0	5	4	0	8	8	0
16 - 20 ..	8	0	0	13	0	0	6	4	0	11	12	0
21 - 25 ..	10	0	0	16	0	0	7	4	0	12	12	0
26 - 30 ..	13	0	0	20	0	0	7	12	0	13	4	0
31 - 35 ..	15	0	0	23	8	0	8	4	0	13	12	0
36 - 40 ..	18	0	0	26	12	0	8	12	0	14	4	0
41 - 45 ..	19	12	0	27	12	0	9	4	0	14	12	0
46 - 50 ..	21	0	0	29	12	0	10	8	0	15	8	0
51 - 55 ..	22	0	0	32	0	0	11	0	0	16	0	0
56 - 60 ..	23	0	0	33	0	0	11	8	0	16	8	0
61 - 65 ..	24	0	0	34	0	0	12	0	0	17	0	0
66 - 70 ..	25	0	0	35	4	0	12	8	0	17	8	0
71 - 75 ..	26	4	0	36	4	0	13	0	0	18	0	0
76 - 80 ..	27	4	0	37	4	0	13	8	0	18	8	0
81 - 85 ..	28	4	0	38	8	0	14	0	0	19	4	0
86 - 90 ..	29	4	0	39	8	0	14	8	0	19	12	0
91 - 95 ..	30	4	0	40	8	0	15	0	0	20	4	0
96 -125 ..	31	8	0	42	12	0	15	12	0	21	4	0

SCHEDULE OF RATES

	SOFT ROCKS			
	New wells		Old wells	
—	Dry	With pumping	Dry	With pumping
0 - 5 ..	3 6 0	6 0 0	..	..
6 - 10 ..	6 8 0	9 0 0	6 0 0	9 0 0
11 - 15 ..	9 8 0	13 0 0	9 0 0	13 0 0
16 - 20 ..	12 0 0	18 0 0	11 8 0	17 0 0
21 - 25 ..	16 0 0	23 0 0	14 0 0	21 0 0
26 - 30 ..	19 0 0	29 0 0	16 8 0	24 0 0
31 - 35 ..	23 0 0	34 0 0	19 0 0	27 0 0
36 - 40 ..	26 0 0	38 0 0	21 0 0	30 0 0
41 - 45 ..	28 0 0	41 0 0	23 0 0	33 0 0
46 - 50 ..	31 0 0	51 0 0	25 0 0	36 0 0
51 - 55 ..	33 8 0	52 0 0	27 0 0	38 0 0
56 - 60 ..	36 0 0	53 0 0	29 0 0	40 0 0
61 - 65 ..	38 0 0	54 0 0	31 0 0	42 0 0
66 - 70 ..	40 0 0	55 0 0	33 0 0	44 0 0
71 - 75 ..	42 0 0	56 0 0	35 0 0	45 0 0
76 - 80 ..	44 0 0	57 0 0	36 0 0	46 0 0
81 - 85 ..	45 8 0	58 0 0	37 0 0	47 0 0
86 - 90 ..	47 0 0	60 0 0	38 0 0	48 0 0
91 - 95 ..	48 8 0	65 0 0	39 0 0	49 0 0
96 -125 ..	50 0 0	70 0 0	40 0 0	50 0 0

SCHEDULE OF RATES

—	HARD ROCKS											
	New wells						Old wells					
	Dry			With pumping			Dry			With pumping		
0 - 5 ..	15	0	0	22	0	0	..			..		
6 - 10 ..	18	0	0	26	12	0	18	0	0	26	12	0
11 - 15 ..	21	0	0	30	12	0	21	0	0	30	12	0
16 - 20 ..	24	0	0	34	12	0	24	0	0	34	12	0
21 - 25 ..	27	8	0	39	0	0	27	8	0	38	12	0
26 - 30 ..	31	0	0	44	0	0	31	0	0	42	12	0
31 - 35 ..	35	0	0	49	0	0	35	0	0	46	12	0
36 - 40 .	40	0	0	58	0	0	39	0	0	51	0	0
41 - 45 ..	45	0	0	65	0	0	43	0	0	56	0	0
46 - 50 ..	50	0	0	75	0	0	47	0	0	61	0	0
51 - 55 ..	55	0	0	86	0	0	51	0	0	66	0	0
56 - 60 ..	61	0	0	95	0	0	55	0	0	71	0	0
61 - 65 ..	68	8	0	100	0	0	60	0	0	76	0	0
66 - 70 ..	76	0	0	112	0	0	65	0	0	81	0	0
71 - 75 ..	82	0	0	123	0	0	70	0	0	86	0	0
76 - 80 ..	90	0	0	131	0	0	75	0	0	92	0	0
81 - 85 ..	95	0	0	141	0	0	80	0	0	100	0	0
86 - 90 ..	100	0	0	151	0	0	85	0	0	110	0	0
91 - 95 ..	105	0	0	161	0	0	90	0	0	120	0	0
96 -125 ..	110	0	0	171	0	0	95	0	0	130	0	0

NOTE.

1. Sinking rates with pumping to be allowed when depth of recuperation overnight is 2 feet and above.

2. In the case of partially step and partially draw wells or wholly old draw wells, excavation in standard dimensions will be paid at the rates for new wells. For excavation beyond the standard dimensions, the P.W.D. district schedule of rates for well sinking will be paid without any extra charges for pumping.

3. For excavation in old step well in standard dimensions, the rate fixed for old wells will be paid. For excavation beyond the standard dimensions P. W D. district schedule of rates of sinking wells will be allowed without any extra charges for pumping.

4. If for want of suitable ledge in (*a*) new well (*b*) step well (*c*) partially step well or (*d*) wholly old draw well, excavation in hard rocks has to be done beyond standard dimensions, the quantity excavated in hard rock to the extent of standard diameter permissible for hard soil will be paid at the rates fixed for the respective wells. Excavation done in hard rock beyond the permissible diameter for hard soil will be paid at the P.W.D. district schedule of rates for well sinking without any extra charges for pumping.

5. For removing the fallen earth due to slips into the wells, a through rate of Rs. 2-8-0 per cent cubic foot below the water level, and Rs. 2-0-0 per cent cubic foot above the water level will be paid.

6. For excavation for blocking steps, P. W. D. district schedule of rates for sinking wells will be paid and whenever necessary pumping charges will be allowed as per Well Sinking Department schedule of rates.

7. For excavating a trench to the extent of 6 feet width in old step wells, the rates fixed for the old wells will be paid. For excavation beyond 6 feet width the P.W.D. district schedule of rates for well sinking will be paid without any extra charges for pumping water.

8. Excavation of power pump chamber will not be seperately paid for.

9. In case of 7 feet polygon and 4 feet septagon, the above rates will be reduced as noted below against each type of the well. (*a*) 7 ft. Polygon: new by $\frac{1}{3}$. old by $\frac{1}{4}$.

(*b*) 4 Ft. Septagon: new by $\frac{1}{4}$. old by 1/5.

If the diameters of excavation are partly suitable for a 4 feet hexagon or a 4 feet pentagon and partly suitable for a 7 feet polygon or a 4 feet septagon, then full rates foı the portion of 4 feet hexagon or 4 feet pentagon will be allowed subject to the reduction as above for those portions. For example, in a 7 feet pentagon well of 55 feet deep, the diameter of excavation up to 40 feet is 14 feet, and the diameter from 40 to 55 feet is 9 feet, then the rates are reduced from 0 to 40 feet, but full rates are given from 40 to 55 feet.

Particulars	Unit	Rate	With Govt. cement	Remarks
		Rs. as. ps.		
Unwatering charges using 20 HP Ford Pump for 3 continuous hours	..	10 8 0	..	..
Unwatering charges for every additional hour	..	5 0 0	..	..
Unwatering charges using 3 to 4 BHP pump for 3 continuous hours	..	4 8 0	..	
Unwatering charges using 3 to 4 BHP pump for every 3 additional hours	..	2 0 0	..	
Slush removal with power pump up to 50 feet depth ..	o/oo Cu.ft.	39 0 0	..	
Slush removal with power pump below 50 feet	o/oo Cft.	41 0 0	..	
Dry rubble masonry for wells ..	o/oo Cft.	22 12 0	..	
Do with Govt. stones ..	do	6 8 0	..	
C.R.S. masonry in foundation in cement mortar of proportion 1 : 6 with contractor's cement	do	41 4 0	20 6 0	
Do 1 : 7 do ..	do	38 8 0	20 6 0	
Do 1 : 12 do ..	do	32 0 0	20 6 0	
C.R.S. in basement in cement mortar of proportion 1 : 6 with contractor's cement	do	43 4 0	22 6 0	
Do 1 : 7 do ..	do	40 8 0	22 6 0	
Do 1 : 12 do ..	do	34 0 0	22 6 0	
C.R.S. in superstructure in cement mortar of proportion 1 : 6 with contractor's cement ..	do	46 4 0	25 6 0	
C.R.S. in superstructure in cement mortar of proportion 1: 7 with contractor's cement ..	o/o Cft.	43 8 0	25 6 0	
1 : 8 do	do	42 12 0	25 6 0	
1 : 12 do ..	do	37 0 0	25 6 0	
1 : 16 do . ..	do	32 12 0	..	
U.C.R.S. 1 : 6	do	39 4 0	18 6 0	
Do 1 : 7	do	36 8 0	18 6 0	
Do 1 : 12	do	30 0 0	18 6 0	
Do 1 : 16	do	25 12 0	..	
Cement concrete lining and plastering to wells excluding the cost of cement	do	45 0 0	..	
Cement concrete lining and plastering of wells proportion 1 : 4 : 8 including cost of cement with an average lead of 60 miles for cement, 2 miles for metal and sand	do	78 0 0	..	

Particulars	Unit	Rate	With Govt. cement	Remarks
Do 1 : 3 : 6 including cost of cement	% Cft.	90 0 0	..	Use of contractro's cement is subject to written permission of the S.O. i/c. W.S.D.
Do 1 : 2 : 4 do ..	do	117 0 0	..	
Do 1 : 2 : 3 do ..	do	140 8 0	..	
Do 1 : 1 : 2 .. do ..	do	188 0 0	..	
Reinforced cement concrete proportion 1 : 2 : 4 including 60 miles average lead for cement and reinforcement and 2 miles for metal and sand ..	Cu. Ft.	2 0 0	..	
Extra lead for every additional mile beyond 60 miles cement and reinforcement ..	do	0 0 1	..	
Fabricating reinforcement including a lead of 60 miles ..	Cwt.	4 0 0	..	
Reinforcement of M.S. bars including fabrication ..	do	19 4 0	..	
Filling behind steining wall with watering and tamping ..				
1. With mooram available from spoils of excavation	o/oo Cft.	9 8 0	..	
2. When mooram is not available from spoils of excavation ..	do	13 8 0	..	
Packing behind steining wall with contractor's stones ..	do	85 0 0	..	
Filling behind steining wall with government stones ..	do	19 6 0	..	
Cement pointing proportion 1 : 3 with government cement ..	o/o Sq.ft.	4 0 0	..	
Fixing charges of pulleys with standards to wells ..	Per pulley	1 8 0	..	
Number plate tablet of cement mortar :				
Manufacture 0 11 0	Each	2 1 0		
Fixing including carting 1 6 0	do			

Particulars	Unit	Rate	With Govt. cement	Remarks
Manufacturing and fixing ¾" diameter iron steps	Each	0 8 0	..	
Stone masonry string course 4" to 8" thick in cement mortar 1 : 12 porportion	Per Rft.	0 2 0	0 1 9	

Signature of Contractor.

Date......... .... *Signature of sub-divisional officer.* *Special Officer i/c W. S. Dept.*

Camp.........................

Sold to Mr............. ....contractor, at.............................

Accompaniment to Sub-divisional officer's No..... ....
....

Dated.........................

NOTE: Due to war (1939-1945) and its consequent after effects the rates were increased uniformly for all areas as follows:

From March 1943 an overall increase of 40% on all items of work.

From June 1944, 75% extra on excavation and 60% on rest of the items.

From April to end of September 1946.

On Excavation :	0 to 35	130%	extra.
	35 —45	125%	,,
	45 —55	110%	,,
	55 —65	100%	,,
	65 —75	90%	,,
	75 —85	80%	,,
	85 & upwards	75%	,,
Other items of work :		100%	,,

For reconditioning works in Raichur district 200% above the pre-war schedule is sanctioned provided the cost of an individual work as per pre-war schedule does not exceed Rs. 1,000.

As the conditions have not improved the following extra percentages have been sanctioned with effect from October 1947.

	Osmanabad, Gulbarga & Bhir districts	Bidar district
0 to 5 Feet.	100%	125%
5 to 10 ,,	125%	150%
10 to 100 ,,	150%	175%
Other items.	100%	125%

The above form of agreement bond which every contractor has to sign and abide by it shows the obvious details of all the items, thus minimising the detailed description of them. The schedule of rates for each district varies, and these rates are shown in each agreement bond for the district it refers to.

Under the above contract well sites are then marked out by either the sub-divisional or sectional officers at sites already selected during preliminary survey of the area by the geologist.

Stocking of cement

As is seen from the agreement bonds that lining of wells is carried on in cement concrete, the details of which are given under "Lining of Wells" entailing the consumption of cement in large quantities. In order to facilitate easy and quick work, the department stocks sufficient quantities of cement, steel etc., costing nearly one and a half lakhs of rupees in the various government godowns at different important centres in charge of responsible officers. These are issued from time to time in quantities from the nearest godowns to the work-spot on indents and the quantity so consumed on the particular well is charged in the measurement book and credited to the account. These godowns are inspected every now and then without notice and stocks checked by a responsible officer.

The cement bags are stacked over a layer of one foot thick stones, the interestices of which are filled with sand in order to prevent dampness of the ground from affecting the cement, and white-ants working their way into the bags.

Before renting godowns for stocking cement, they are carefully examined to see that the roofs are water-proof, and if any subsequent leaks start in the ceiling, they are repaired through the owner or the department. The cement bags are stacked away from the walls allowing sufficient space for a man to easily pass round the stack and to check.

As far as possible cement is stacked only in one or two main godowns in a section from where they are sent to the work spot as required.

Before fresh stocks are stored, the old stocks are sent to works or removed from the bottom, to a separate place so that they may be used in preference to the new stocks received.

These are of hexagonal or pentagonal forms made of $\frac{1}{8}$th inch M. S. plates and $1\frac{1}{2}''$ angle iron frame. The plates are fitted together with removable pins. These moulds are supplied on hire from the departmental workshop stores on rents. When the moulds are returned to stores, they are to be delivered in good and clean form failing which the contractor would be charged whatever that is spent on rectifying and cleaning the moulds.

Moulds for C.C. lining.

Explosives

The characteristics of a good blasting explosive are (1) sufficient stability or difficulty of detonating by mechanical shock and strength (2) Convenience in form and safety in handling ; (3) absence of injurious effects on the user.

Explosives are of two general classes low explosives or those discharged by fire and high explosives or those that require a detonator.

Kinds of explosives.

Gunpowder or black powder is a type of low explosive consisting of 73 parts of Chili Saltpetre (Nitrate of Soda. $NaNO_3$), 16 parts of charcoal and 11 parts of sulphur. These are graded according to the size of grains that pass through various sizes of round hole sieves. The shattering effect is the result of the rapid combustion of oxygen with carbon, the sulphur being added to help in the ignition of the mixture.

Low explosives.

Size of grains of black blasting powder

Trade mark	Through	Over
C. C. C.	40/64	32/64
C. C.	36/64	24/64
C.	27/64	18/74
F.	20/64	12/64
F. F.	14/64	7/64
F. F. F.	9/64	3/64
F. F. F. F. ..	5/64	2/64

These are commonly called dynamites regardless of their composition and generally derive their names from those of their active principle. Of the various types of dynamite, the gelatine dynamite has been used to a large extent in general and in particular in damp or wet blasting. These are safe to handle and form the most economical explosive for most types of work, besides their low weight, which is an important consideration for transport. In the manufacture of these dynamites the nitroglycerin is gelatinised by the addition of small percentage of nitrocellulose. The jelly-like mass thus formed is impervious to water and is of high density and plasticity, the latter property permits of its being squeezed to take the shape of and thus completely filling the bore-hole. Unless it is necessary to submerge it for several hours under water, it can otherwise be used without any water-proof covering. These dynamites are safe to handle and will stand ordinary shocks without explosion but, however, boxes containing them should always be handled carefully.

High explosives.

The composition of gelatine dynamites generally offered for sale are given below:

Analysis of high explosives

Constitutent	40% strength low freezing dynamite	40% straight nitroglycerine dynamite	40% strength ammonia dynamite	40% strength gelatine dynamite
Moisture ..	1.13	0.97	0.88	1.47
Nitro-glycerine ..	27.56	39.19	21.60	30.70
Nitro-cellulose ..	..	..	..	0.88
Ammonium nitrate ..	..	..	18.86	..
Nitrotoluene ..	10.13	..	..	..
Sodium nitrate ..	51.54	49.53	46.04	54.27
Wood pulp ..	8.52	9.77	5.45	8.58
Sulphur	..	..	4.85	3.08
Zinc oxide ..	..	..	0.88	1.02
Calcium carbonate ..	1.12	0.54	1.44	..
Total ..	100.00	100.00	100.00	100.00

The table below gives the relative strength of the different high explosives as determined from an extended series of tests by the Bureau of Mines. In all cases, 40 per cent straight nitroglycerine dynamite has been taken as the standard with a value of 100 percent. Disruptive effect indicated represents averages of energies developed in the Trauzl lead block small lead-block, and rate of detonation tests propulsive effect indicated represents averages of Ballistic pendulum and pressure guage test.

Comparative strength of explosives.*

Results of tests to determine potential energy and disruptive and propulsive effects of Dynamites

Class & grade	Percentage strength representing potential energy	Average per centage strength representing disruptive effect	Average percentage strength representing propulsive effect
30 per cent. straight nitroglycerine dynamite ..	93.1	94.1	96.8
40 per cent. do ..	100.0	100 0	100.0
50 per cent. do ..	111.0	109.2	107 4
60 per cent. do	104.0	119.8	114.9
60 per cent. strength low freezing dynamite ..	60 2	93.5	91.2
40 per cent. strength ammonia dynamite ..	101.8	67 9	99.1
40 per cent. strength gelatine dynamite	105.7	78 4	95.8
50 per cent. granulated nitroglycerine powder ..	67.6	21.6	53.3
Black blasting powder ..	71.6	6.8	58.6

From the above table it is seen that though the potential energy of 40 per cent strength ammonia dynamite and of 40 per cent strength gelatine dynamite (that is the theoretical maximum work that these explosives can accomplish) is higher than 40 per cent straight nitroglycerine dynamite, yet the disruptive and propulsive effects, which represent the useful work done as shown by actual tests, are less than those of 40 per cent dynamite. While it is true that straight dynamites possess greater shattering effect than other standard

Coal Miners Pocket Book. Formerly the Coal and Metal miner's Pocket Book, 1916. P. 670.

types of explosives, they are being rapidly displaced by the ammonia and gelatine explosives on account of the greater safety in handling characteristic of the latter.

Ordinary black blasting powder has only about one-third of the disruptive effect of granulated nitroglycerine powder.

Position of dynamites while stocking

Dynamite cartridges should always be laid on the side and not stood on end, for in the latter position the nitroglycerine may ooze out from the dope and collect in the bottom of the cartridges.

Thawing of dynamites.

During winter such dynamites freeze at about 45° F., and in this condition they explode with difficulty and with partial detonation. It is then dangerous to cut, break or ram a frozen dynamite cartridge, as the crystallised nitroglycerin may explode. Dynamites should never be used in this frozen condition, but before use they must be thawed and made soft and plastic, and failure to observe this precaution would lead to accidents. When incomplete detonation occurs by the use of frozen dynamites unexploded powder is often left in the holes or in the material blown down by the shot.

While thawing dynamites, care should be taken to keep the temperature from rising high. The thawing should not be done before a naked fire or flame, or on a shovel, in a tin can or in an oven for though it may burn in the unconfined open space, yet it is likely to explode. Dynamites should not be thawed by immersion in hot water as this process will leach the nitroglycerin and make it dangerous.

The thawing of dynamite may be done by placing it in a tight box surrounded by fresh manure, which will give sufficient heat for the process. Usually when the consumption of dynamites is too great in winter, the thawing is done in specially constructed thawing rooms of 12 by 16 feet whose temperature must be regulated between 75° and 80° F.

For small quantities, special thawing kettles may be employed. These are of metal cans having tubes which are surrounded by water. The dynamites may be placed in these tubes and covered, and the water warmed to the required temperature, so as to thaw out the cartridges.

Means of firing high explosives.

Dynamites are fixed by means of detonators or caps, consisting of copper capsules about as thick as an ordinary lead pencil, which are commonly

charged with dry mercury fulminate or with admixture of mercury fulminate and potassium chlorate which is compressed in the bottom of the capsule, filling it to about one-third its length. Several grades are on the market but to secure perfect explosion No. 6 strength containing 15.4 grains of charge are recommended and used by the department. Fulminate of mercury is extremely sensitive to heat and friction and blows ; for these reasons it should be handled with much care, otherwise violent explosions may result.

The following precautions are recommended in handling them :

1. Never attempt to pick out any of the composition.

2. Do not drop caps or strike them with anything hard.

3. Do not step upon caps or place them where they may be stepped upon.

4. When crimping caps on to the fuse, care should be taken not to squeeze the fulminate and never crimp with the teeth.

5. Caps should be stored in a dry place and in a separate building from the explosives.

6. Caps should not be carried with other explosives or placed near other explosives except in a bore-hole.

Fuse.

Fuse otherwise called the safety fuse or Brickford's fuse, from its inventor, consists essentially of a central core of fine grained gun-powder, wrapped about by threads of hemp, jute or cotton. These threads are wound in two sets, the inner being known as the spinning threads and the outer as the counter threads. In simple tape fuse, the threads are wound with tape and then coated with tar and covered with fullers earth or powdered talc to prevent sticking. Double tape fuse is single tape which is also tarred and powdered. Cotton or hemp fuse, not tape wound, is also made and is only suitable for use in absolutely dry places or in hot climates. In cold countries, fuse covered with tar is apt to crack and thus become wet and misfire, while in hot countries it becomes sticky and unfit for use. For these reasons special fuses are manufactured for use in either arctic or tropical regions. For use under water, gutta-percha covered fuse has been made.

Classes of fuse.

According to the work in which it is intended to be used fuse may be divided into four classes. Fuse of the first class is suitable for dry work such

as strump blasting and quarrying ; it is usually untaped hemp and cotton fuse. Fuse of the second class is intended for damp work as in coal mining or surface work where mud rain or dampness is encountered ; it is commonly of single tape variety. Fuse of the third class is suitable for very wet work such as tunnelling and shaft and well sinking etc. Fuse of the fourth class is designed for submarine work ; double tape, triple tape, gutta-percha and taped double countered fuse belong to these classes. Owing to the large amount of carbonaceous material in the wrappings of the fuse, the gases produced by its burning contain a large proportion of carbon-monoxide CO.

The rate of burning of the better grades of American fuse has been determined by the Bureau of Mines to be very nearly 30 seconds per foot length, with a variation of some 10 percent either way.

Blasting by dynamites are dealt with in detail under 'rock excavation' for wells.

The explosives used on rock blasting for well sinking are the gelatine dynamites. These are stocked in the magazines built on standard designs and away from habitation at the headquarters of the Special Officer and the sub-divisional officers. These are issued to contractors in conformity with rules as detailed elsewhere. The stocks in the magazines are checked from time to time to avoid any unforeseen or legal complications.

Conditions for a good store

The buildings where the explosives are stocked are kept scrupulously clean at all times free from grit and iron materials. The doors are always kept locked and the key kept by a responsible person usually the headstore-keeper at headquarters, and by the sub-divisional officers at the sub-divisions. This room is only intended for explosives and all tools connected therewith are of copper, bronze or of some soft material, other than iron.

Detonators are kept in separate rooms constructed for the purpose.

Buildings in which explosives are stored for more than 6 months come under the category of magazines ; consequently their location has to be intimated to the Director-General of Police.

The contractors are not generally expected to keep their stock of explosives in a place for more than 6 months, but in

cases where these are kept in one place for more than that period, the sub-divisional officers should communicate the name of the persons who own the keys and the material.

If any repairs are needed to the magazine, all the explosives are removed and any dust left behind is washed out of the interior of the building. If repairs can be executed between sunrise and sunset no objection will as a rule, be raised to remove them on to planks in the open and cover them with tarpaulins, but if the repairs are to be of longer duration, the head store-keeper should refer the matter to the Special officer for orders in the matter.

Care and use of explosives by contractors

1. The contractors will as far as possible take delivery of the explosives personally, but if for any unavoidable reasons, they cannot present themselves at the stores, they may depute their very reliable men whose name is endorsed by the contractor, both in the indent and invoice, but the responsibility solely rests on the contractors.

P.W.A. FORM NO. 7 I.

Indent No...

on...

Dated..................

Description	No. or quantity	Head of account

These stores should be $\frac{\text{delivered}}{\text{despatched}}$ to,....................

..................................by.......................

Indenting Officer.
(Divisional or Sub-divisional officer)

P.W.A. FORM No. 7 II.

Indent for Stores

(See page 629 of the P.W.A. Code)

Indent No..................... ....

on...... ....

Dated..........................

Description	No. or quantity	Head of account

Indenting officer.

(Divisional or Sub-divisional officer)

Certificate of Supply

This indent has not been complied in full...... ....

....

(The alteration which I have attached have accordingly been made by me)

delivered to / despatched .... .on..... . ...

Dated. .... .F.

Supplying officer.

P.W.A. FORM No. 7 III.

Invoice of stores supplied.......................................

by.... .. ..

to...... ....

on indent No........ d/....................issued by the......

....

Description	No. or quantity	Head of account

Dated........................1 F.

Supplying officer.

In the case of issues to contractors and private persons this acknowledgement should set forth all the particulars mentioned in para 673 of the P.W.A. Account Code.

Received...................

Dated.........................13 F..

Receiving officer.

2. Indents for explosives are invariably signed by the contractors themselves and endorsed by the sectional or sub-divisional officers. The sectional or sub-divisional officer, before endorsing the indents, checks the contractors' accounts of explosives to satisfy himself the balance on hand justifies further indent and that the quantity indented for is not more than a month's requirement. The contractors are advised that it is safer to purchase explosives by piecemeal instead of in heavy consignments which would require more care and elaborate arrangement for storage. The following form is maintained by the contractors at each of their work spot and the maistry should enter the daily consumption with initials. If any quantity is transferred to other works of the same contractor the word ' transferred to.... work ' is written in the column meant for ' consumption of explosives.'

The sub-divisional and sectional officers and other subordinates of the department in charge are to check the amount of explosives at each work as per statements maintained by the contractors at the work spot.

[*Statement.*

W. S. D. Form No. 19.

Daily register of explosives used by the contractors on work site

Date	Receipt		Consumption of Explosives		Nature of work on which used	Balance		Initials of sectional officer or sub-division-al officer
	Dynamite	Detonators	Dynamite	Detonators		Dynamite	Detonators	

3. Explosives are sold in the stores between 10 a.m. and 12 noon to facilitate their conveyance the same day to the workspots. The head store keeper is authorised not to issue the explosives unless he is satisfied about the proper arrangement by the purchaser for their safe carriage.

4. Explosives are not to be carried by passenger, or bus service, nor are the dynamites and detonators kept together during transit. Contractors are strictly warned against this method of conveyance as these are strictly against the Government of India Explosive rules the contravention of which would involve very heavy punishments.

5. The carts or coolies are arranged before the explosives are taken delivery of from the stores to avoid the necessity of keeping the explosives at unsafe places. If, for any reason they are not carried to the work site on the same day they are purchased the purchaser can approach the head store keeper before 4 p.m. for their temporary safe custody in the magazine labelled ... pounds of dynamite and.... (No.) detonators sold to Mr.......................kept in temporary custody. The head store keeper passes a receipt to the depositor, who is to return this receipt when he takes back the materials the next day. A register to this effect is maintained by the head store keeper in the following form.

Date	Time	Name of contractor or his messenger depositing the explosives	QUANTITY OF EXPLOSIVES Dynamite Detonator	Date & Time of Return	Acknowledgement by the Depositor

The register is kept in the magazine and a responsible officer inspects it from time to time.

6. It is not obligatory on the department, to inform the police in case of ordinary injuries, yet it is advisable for the contractors to intimate the matter to the nearest police office or village police patel. Serious accidents should, however, be reported to the Police Department. The injured persons, whether ordinarily or seriously, are removed at once to the nearest Government Hospital.

7. During blasting operations the labour and other people, and occupants of houses nearby are warned not to be within a distance of at least 200 yards. When blasting is in progress efficient arrangements for getting in and out of the well are made. Rope ladders are more serviceable and useful. In case of deep wells delay action detonators are preferable so that there may be no danger for workmen while getting out of the well.

8. While blasting is in progress care will be taken by the contractors to protect the pump and the hose from being damaged.

Storage of Explosives

(*From Explosives Act of* 1875).

" It will be found that the best means of keeping them in small quantities is in a small box provided with a good lock and key and labelled or otherwise marked " Explosives." The box should be kept in fairly close proximity to one of the exits of the building in which it is placed so as to facilitate its removal in case of fire, in which event, the box should be wrapped in a wet blanket and carried away to a place of safety. It is prohibited to keep sporting cartridges or detonators in close proximity to blasting explosives.

" Nobel Industries Ltd. desire to warn persons who have no previous knowledge of the danger involved in the use of high explosives. In skilled hands they are comparatively safe, but in unskilled hands they are most dangerous, and their storage under careless condition, in private houses has been a fruitful cause of most distressing accidents, not only to persons actually using them, but also to the unsuspecting women and children. This applies with particular emphasis to detonators, which annually exact a heavy toll of serious injury to children, who attracted by their bright appearance are lead to investigate their contents.

" It should be particularly noted that explosives containing their own means of ignition, such as percussion caps,

detonators, and sporting cartridges, must not be kept with other explosives not containing their own means of ignition, such as gunpowder, bobtrinite or high explosives. Gunpowder can best be kept in the following manner:

"For keeping smaller stocks, a receptacle can be used. This may either be properly constructed "Fireproof safe" or any, substantial receptacle such as cupboard, box or drawer under lock and key, which are exclusively appropriated to keeping explosives, and which are placed inside the shop, house, office or warehouse.

"Probably the best form of such a receptacle is a steel travelling trunk, placed conveniently for removal in case of an alarm of fire. The use of a fireproof safe is not advised; no safe yet made is absolutely fireproof, they are only more or less fire resisting and the storage of explosives in such receptacle may, possibly in case of fire, only defer an explosion until the fire brigade and a large crowd of people have collected. Owing to the stong confinement provided by a safe, its explosion is far more strongly developed, than would be the case with the light steel trunk; and owing to its great weight, it is impossible to remove it on an alarm of fire. Whilst on this subject, it would be well to suggest to occupiers of registered premises the advisability of having a considered plan of action to be pursued in case of fire and all assistants instructed therein. Even a bad plan, thought out beforehand is better than no planat all, as it tends to allay panic."

Transferring of explosives

Transferring of explosives from one sub-division to another is strictly forbidden except in cases mentioned already as such a transaction is likely to create confusion in the accounts, but in cases of great urgency, they may be transferred on obtaining the written permission of the sub-divisional officers. The contractors are also informed that the unspent quantity of explosives left after completion of their works, will be purchased back by the department.

Use of gunpowder.

The department does not stock or supply gunpowder to contractors and if they deem it profitable and convenient, they can purchase their requirements for use on their works from elsewhere.

At the end of the year, a consolidated statement is submitted to the office showing the quantities of gunpowder purchased by each contractor for the year.

Extra precautions on explosives

As this manual was formed during 1943 when disturbed conditions were prevalent and sabotaging was getting common some extra precautionary measures which were adopted can relevantly be mentioned here.

1. The issue of explosives at any time to any contractor is limited as detailed below:

Dynamites	100 pounds.
Detonators:	1000.

In cases where greater quantities than that mentioned above are needed, the contractor should produce the recommendations of the sub-divisional officers, who should satisfy themselves of the validity of this extra requisition. This excess stock of explosives issued to contractors are to be kept in the government magazines, and issued as and when required. A separate register is to be maintained for all such deposits showing issues, receipts and the name of the authorised person taking delivery, etc. should be noted.

2. The contractors are requested to exercise the maximum possible care and watch over the explosives under their charge to avoid them getting into unwarranted hands.

3. Besides the present system of maintaining full accounts of the dynamites, detonators, fuse, etc., a clear and accurate account of the receipts, issues and balances of gunpowder under the custody of the contractors is caused to be maintained both at the work sites and their magazines wherefrom issues are made.

The mechanical engineer, sub-divisional officers as well as sectional officers are requested to maintain extra vigilance to see that the above instructions are scrupulously followed by the contractors, and to report the slightest irregularities to Special Officer under a separate letter marked "Confidential and most urgent."

Transport of materials purchased by the Government

Carting agents.

The materials such as cement, steel, explosives, etc., purchased by the government for use in well sinking, requiring clearing and carting to respective places, are entrusted to carting agents chosen on tenders and agreements contracted in the following manner.

W. S. D. FORM No. 61.

H.E.H. THE NIZAM'S WELL SINKING DEPARTMENT

Notice Inviting Tenders for the Forwarding Agency for........ ....District.

Tenders are invited for the forwarding agency for the year........................for........................ district. This constitutes the undertaking of delivery of goods and parcels of all kinds arriving at................ railway station........................railway, and forwarding them on by cart or other conveyance to whatever destination the delivery of the parcels is ordered; and similarly to receive and book by railway any consignment to other railway stations from......................station. The successful tenderer shall have to maintain at his cost a godown accommodation approved by Special Officer in charge, Well Sinking Department. Those who wish to tender are requested to submit their tenders in sealed covers to the Special Officer in charge, Well Sinking Department........ on, or before..................with a security deposit of Rs....................... The tenders are to be in prescribed form which can be had from the office of the Special Officer in charge Well Sinking Department........ at a cost of Re. 0-8-0. each. The tenderers should quote their lowest rate for the following:

1. Unloading or loading charges from and to railway wagons for articles, the total weight of which as per railway receipt (each consignment) is above five seers including carrying or carting to the forwarding agent's godown.

The rate would not apply to cement.

Per maund of 80 pounds:—....................

Note.—Parcels weighing five seers or less will be despatched or taken delivery of, free of charge.

2. Unloading of cement from railway wagons and carting to forwarding agent's godown.

Per cart load of 13 cwts........................

3. Carting including loading and unloading of carts —including cement and other materials—from railway station to any of the places in the district and vice versa.

Per cart load of 13 cwts........................

The above rates to include toll-tax if any.

The forwarding agent will have to keep sufficient number of tarpaulins of his own and other necessary coverings.

The forwarding agent should take delivery of railway goods and pay freight ; and the actual payment so made will be refunded by this department, on production of railway vouchers.

The goods received must be depatched within a week after the receipt ; otherwise the department will have the right to get the articles carted and to charge the extra cost if any to the forwarding agent.

Cost of damages and shortages during transit will be recovered from the bill of the forwarding agent. Replacement in kind will not be allowed.

The forwarding agent will have to enter into an agreement in accordance with the conditions laid down by the department.

Non-compliance of the conditions therein may result in forfeiture of security deposit.

The Special Officer with whom a duplicate key of the godown should be kept, will be at liberty to get the lock of the godown opened in the absence of the agent at the forwarding agent's entire responsibility, for checking the contents of the godown or for any other purpose.

A card should be kept in the godown posted up to date showing the ground balances besides maintaining register of daily receipts, issues and balances.

The successful tenderer's security deposit will be retained while that of the others refunded.

The right to reject each or all of the tenderers without assigning any reason, is reserved.

SPECIAL OFFICER *i/c*
Well Sinking Department.

No........................Dated..................

Forwarded to..

for information.

SPECIAL OFFICER *i./c*
Well Sinking Department.

W.S.D. Form No. 62.

To TENDER FORM No...........

The Special Officer-in-Charge,
Well Sinking Department,

....

Sir,

As laid down in the notice inviting tenders for the carting agency at........................for the year.......... I, having deposited the security deposit of O.S. Rs......... in............................treasury, through challan dated:......................certified copy of which is enclosed, beg to tender for the said agency at the following rates.

1. Unloading or loading charges from and to railway wagons for all articles, except cement, including municipal and toll-tax, godown rent and carrying and carting to the godown.

Per maund of 80 lbs....................Rs........

Note.—Parcels weighing 5 seers or less will be despatched and taken delivery of, free of charge.

2. Unloading of cement from railway wagons and carting to godown including municipal and toll-tax and godown rent.

Per cart load of ....Rs...............

3. Carting including loading and unloading of carts and municipal and toll-tax, etc., for all materials from railway station to any of the places in the district and vice versa.

Per cart load of...................per mile........
Rs....................

I hereby agree to abide by the conditions mentioned in the aforesaid notice and the standing orders of the department.

I beg to remain,
Sir,
Your most obedient servant,

Date.................... *Tenderer.*

W.S.D. FORM No. 64.

H.E.H. THE NIZAM'S GOVERNMENT

Well Sinking Department

This Agreement made this day of................by Mr........................son of .... resident of...........................(hereinafter referred to as the carting agent) of the one part and Government represented by the Special Officer-in-Charge, Well Sinking Department (hereinafter referred to as the government) of the other part witnesseth :—

I. The carting agent shall take delivery of all consignment arriving at......................railway station and pay freight charges, etc. He shall pay for any demurrage that is incurred due to delay on his part in taking delivery of the goods and shall not claim such charges from the government.

II. A godown approved by the Special Officer-in-Charge, Well Sinking Department, shall be maintained by the carting agent. A duplicate key of the same shall be given to the Special Officer-in-Charge, Well Sinking Department, who, if necessary, shall open the go-down and cart any materials required urgently (vide clause 3) without being liable for any shortage found in the godown other than the materials removed.

III. The carting agent shall store all government consignment in the godown when required. Cement shall invariably be carted to the godown. He shall be responsible for any damage and shortages in his godown.

IV. The carting agent shall safely cart all government articles arriving by rail with the utmost speed and without avoidable delay.

The delays of more than 7 days from the date of unloading of articles to the date of receipt at their destination, the carting agent agrees to pay a penalty of Re. 0-8-0 per cart load per day, provided the delay is not caused by circumstances beyond human control.

Explosives shall invariably be carted on the day their delivery is taken.

The following charges and rates shall be paid by government to the carting agent:—

1. Unloading and loading charges from and to railway wagons for articles except cement the total weight of which as per railway receipt (each consignment) is above 5 seers including municipal, toll-tax and godown rent and carrying or carting to the godown.

Per maund of 80 pounds :..............Rs...........

NOTE.—Parcels weighing 5 seers or less will be despatched and taken delivery of, free of charge.

2. Unloading of cement from railway wagons and carting to godown including municipal and toll-tax and godown rent.

Per cart load of...................Rs.............

3. Carting including loading and unloading of carts and municipal and toll-tax, etc., for all materials from railway station to any of the places in the district and vice versa.

Per cart load of.....................Rs..........

4. *Further.*—The carting agent shall cart cement during rainy season if ordered, and shall be responsible for any damage or loss in the transit. The cost of damaged or lost cement shall be recovered from his bills.

5. In case of failure or delay on the carting agent's part, the government reserves the right to cart the materials departmentally or through any other agency and charge the excess over his approved rate, to the carting agent. The other charges that the government may incur in deputing an officer for this purpose are also to be charged to the carting agent.

6. The amount due to the carting agent shall be withheld by the government and paid to the cartmen, if he be found not paying the cartmen their dues.

(*a*) The actual railway freight paid by the carting agent shall be refunded to him on submission of money receipts passed by the railway authorities.

(*b*) Full cartage will be paid by the carting agent to the cartmen. The cartage amount as per approved rates for cartage shall be paid to him by the department on submission of bills and acknowledgement received for the full quantities despatched.

(*c*) The clearing charges will be paid to the carting agent only after the materials have been carted to the respective places.

7. The carting agent shall keep a sufficient number of tarpaulins and other necessary coverings of his own, for cartage of cement and other such articles to protect them against rain and weather.

8. Bills shall be submitted by the carting agent in triplicate fortnightly or monthly.

9. In token of agreement to fulfil the above conditions the carting agent has deposited O.S. Rs.................. which shall be refunded to him after the satisfactory fulfilment of the contract and after he has returned all government materials and paid the government dues and has obtained a clearance certificate failing which the government shall be at liberty to confiscate this amount and his other dues.

10. Should any dispute arise, the decision of the Special Officer-in-Charge, Well Sinking Department, shall be final and binding.

Carting Agent.

Date :—........................

Signed on behalf of His Exalted Highness the Nizam's Government in token of agreement with the above conditions on the day..................of..............13 F.

SPECIAL OFFICER i/c
Well Sinking Department.

Maintenance of Account by the Carting Agent

The various accounts and forms referred to in the agreement bond, that the carting agent has to maintain are herein amplified.

1. The carting agent should maintain the following ledgers in the enclosed forms posted up to date and produce for verification of the inspecting officers as required by them.

(*i*) Receipts, despatches and balances of all articles under his charge.

(*ii*) Receipts and despatches of small packages.

(*iii*) Allotments and despatches to sectional officer, etc.

The materials should be properly arranged in the godowns so that the inspecting officers could easily check them up.

Methods of posting of registers are explained below.

Receipts, Despatches and Balances of Articles under the charge of Carting Agent.

A few pages are allotted for each of the materials (say 50 pages for cement, 30 pages for panel reinforcements and 20 pages for pulleys).

The first half of the form (from columns 1 to 8) is meant for deliveries taken and the second half (from columns 10 to 17) is for despatches. Column No. 9 is common for both receipts and despatches.

W. S. D.

Ledger of Receipts and Despatches of Articles other than Cement,

Ref: to Ry. receipt		Weight as per R. R.		Railway freight			Wharfage			Date of delivery	From whom received
No.	Date	Mds.	Srs.	Rs	a.	p.	Rs	a.	p.		
1	2	3		4			5			6	7

W. S. D.

Ledger of Receipts, Despatches and Balances of Cement,

Ref: to Ry. Receipt		Weight as per Ry. Receipt		Ry. Freight	Wharfage	Date of delivery	Ref: to office letter No. and date under which Ry. R. received		From whom received or to whom despatched
No.	Date	Mds.	Srs.	Rs. As.Ps.	Rs As. Ps.		No.	Date	
1	2	3		4	5	6	7	8	9

FORM No. 69

Panel Reinforcements and Small Bent Pulleys

Reference to office letter No and date under which R.R. is received		Particulars	Quantity	Despatch memo		Quantity despatched	To whom despatched	Remarks
No.	Date			No.	Date			
8		9	10	11		12	13	14

FORM No. 70

Panel Reinforcements and Small Bent Pulleys

Despatch Memo		Parti-culars	Previous Balance	Receipt	Total	Despatches	Balances	Remarks
No.	Date							
10		11	12	13	14	15	16	17

CARTING BILL Camp.

Bill No. Date.

Name of carting agent

To

THE SPECIAL OFFICER-IN-CHARGE,

Well Sinking Department.

Cart memo		No. of carts	From	To	Distance	Descrip-tion of materials	Rate per		Amount	Re-marks
No.	Date				Miles		Mile	Cart	Rs. a. p	
1	2	3	4	5	6	7	8	9	10	11

Signature of Carting Agent.

Receipts and Despatches of Small Packages.

These are entered in a similar way as the above. Columns 1 to 10 are for receipts and columns 11 and 13 for despatches, column 14 needs no explanation.

Despatch of packages in columns 11 to 13 should be noted against the entries of receipts although the packages may be despatched on some other date. This will show at a glance, whether the packages received have been despatched or not.

Allotments and Despatches of Materials to Sectional Officers, etc.

A few pages should be allotted for each sectional officer to whom the carting agent may have been ordered to send the materials and the allotments ordered by this office and the despatches made by the carting agent from time to time are posted as the transactions occur. This would show at a glance the quantity of materials despatched and to be despatched.

Carting memos.

Every despatch should accompany a memo from the carting agent in the enclosed specimen form. These memos should be in a bound book serially numbered in triplicates. The triplicate copy will form the office copy of the carting agent.

The original and the duplicate copies should be sent along with the cartmen. The receiving party will retain the original and return the duplicate copy with the cartmen duly acknowledging the safe receipt of materials or making necessary remarks in cases of shortages and damages. The carting agent should attach this memo with his bill for cartage, which

will be verified with the original copy, received from the receiving party with the indent.

The memos should be written in Urdu or English.

W.S.D. Form No. 68.

Cart Memo.

No. Camp

Date

To

(Name of Sectional Officer or Party).

(Place)...........................

....

Dear Sirs,

Please receive in good order and condition the undermentioned goods and acknowledge the same in the duplicate copy herewith attached :

Quantity	Description of goods	Number of carts

Signature of carting agent.

Bills. The carting agent should submit his bills in triplicate in the enclosed form. The bill should accompany railway vouchers and carting memos. Claims for cartage of materials not supported by carting memos would not be paid, though the materials might have been despatched, as such claims delay the disposal of the bills.

Clearing charges should be claimed only for those materials that have been completely carted.

BILL FOR CLEARING AND FREIGHT CHARGES.

Camp :—
Date :—

12*Name of carting agent :—

Bill No. :—

To

The Special Officer-in-Charge,
Well Sinking Department,
....

Date	Details of articles	Ry. Rt. received from	Letter with which Ry. Rt. is received		Ry. Receipt				Amount Ry.Freight	Paid Wharfage	Clearing charges		Classification of charges
			No.	Date	No.	Date	Weight				Rate	Amount	
							Mds.	Srs.	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.	

Signature of Carting Agent.

At the end of each month, the carting agent should submit W.S.D. Form No. 32 in duplicate duly showing therein the transactions for the month. After verification the original will be retained and the duplicate copy returned to the carting agent. These forms can be purchased from the department at Re. 0-1-0 each.

Transportation of Materials for Government Works through British Limits

On articles imported from outside the State, duty (customs) is charged on all private goods excepting articles meant for government use. In order to avoid inconvenience to the contractors, while materials are being transported to government works through the British limits, a certificate duly signed by a responsible person of the department should follow each such consignment so that the State Customs Nakas situated at every important point on the outskirts of the State, may pass the materials.

These printed forms are bound in books and they are kept by the sectional officers and the head store keeper; for materials going out of stores, the latter will issue the necessary certificate, while for materials coming into stores, such a certificate will be issued by the former officer.

Pumps for dewatering

When sinking is done below water level, the well is first dewatered which is usually done by means of mhots which also serve for hoisting the excavated materials, muck, etc. In cases where complete bailing of water cannot be done by mhots, the use of the pump is resorted to. Formerly these pumps were lent to contractors on hire from the department who, besides bearing up, 'to and fro' and their running charges, were induced to employ skilled drivers with a view to preventing damages and accidents to pumps as far as possible. Further it was made obligatory on the part of the contractors in the year 1936 to employ only such drivers who were found conversant with the technique of handling and driving the pumps, after being tested, certified and licensed by the mechanical engineer of the department with the countersignature of the Special Officer. The form of license issued is shown below.

[*Statement,*

H.E.H. the Nizam's Government, Well Sinking Department

License No.................

Dated........

The license is issued to Mr...........................

Here comes the photo of the driver to whom the license is issued.	authorising him to work as driver on government pumps.

Special Officer-in-Charge,
Mechanical Engineer. *Well Sinking Department.*

Date of renewal	Date of expiry of license	Signature of mechanical engineer	Signature of Special Officer

Fines

Date	Amount	Reason	Signature of the Mechanical Engineer & Special Officer

Contractor under whom engaged

Name	Salary	Date		Signature of mechanical engineer
		From	To	

While on work the driver should keep the license with him, failing which he will be fined Re. 0-4-0 and recovery will be made through the contractor. Three fines mean cancellation of license and dismissal from service.

The following will result in immediate cancellation of license and automatic dismissal from service.

i. Bad conduct.
ii. Incurring debts.
iii. Habituated to drinking.
iv. Neglect of duty.
v. Deliberate damage to government machinery and other materials.
vi. Harassing the contractor.
vii. Disobedience of orders of the mechanical engineer, sub-divisional and sectional officers.

Service of the driver is subject to termination on 15 days notice on either side, failing which the party concerned (contractor or driver) should forego salary for 15 days.

License will be renewed annually by the 15th October on payment of Re. 0-8-0, but if renewed between 15th and 30th October Re. 1-0-0 will be charged and after that, a penalty of Rs. 5-0-0 will be levied.

Some contractors who have purchased pumping outfits from the department are not exempt from employing skilled and licensed drivers.

Any government loaned pump outfits which cannot be repaired on the spot by government fitters, stationed at different centres for this purpose, will, on their being sent to the workshop of the department, be repaired and the charges, plus ten per cent supervision, recovered from the contractors along with the up and down conveyance charges.

If the contractor's pumps are repaired by fitters on the work site, the latter are to obtain a certificate from the former, his agent, or driver, whoever is present at the work site for the satisfactory repair carried out by them and submit it along with their weekly diaries in the following form, to avoid any complaints from the contractors.

Fitter................attended the power pump No. ....working on................well on .. ..has done the necessary repairs and put the pump in working order.

Camp....... ....

Date............. ....

Signature of contractor.

The pumps owned by contractors cannot be sold or disposed off in a manner they choose to the detriment of well sinking work and without the knowledge of the department.

A pump book for every pump is maintained to enable the inspecting officers to check the work of the government fitters.

The services of the mechanical engineer can be requisitioned by the contractors in cases where the government fitters stationed at respective centres are not able to effect proper repairs to the pumps. If any spare parts are required they may be obtained by the following methods.

Spare parts :

1. If the required spare part is small enough and can be received by post, requisition is sent to the Special Officer by the sub-divisional or sectional officers, giving details of postal address to which it has to be despatched along with the name of the contractor who needs it.

2. If the spare part required cannot be got by post, the contractor himself may come to the workshop stores or depute one of his men with necessary requisition from the

sub-divisional or sectional officer. The contractors while purchasing new parts for their pumps from stores, are required to leave the old worn out parts in the workshop to utilise the material and thus effect a reduction in sale price.

3. When it is not possible or economical to carry out the above two procedures, then the sub-divisional officer can authorise the fitter to go over to stores to get the required part, but this cannot be insisted on by contractors as a rule; in extraordinary cases, this procedure is adopted and the sub-divisional officers can use their discretion in the matter.

Cost of spare parts will be debited to the contractor if the breakage is due to his neglect, in case of government pumps.

Test in the work-shop

In cases where the contractors take government pumps on hire, they are carefully tested in the workshop before being sent out to them. If the contractor deputes his driver to take charge of the pump, then it will be tested by him in the presence of the mechanical foreman or fitter or otherwise before the working staff. The contractor will be charged Re. 0-8-0 for a test on each pump he receives.

Transferring pumps and moulds

Whenever government pumps or moulds are to be transferred from one contractor to another in the same or other sub-division the following procedure is adopted:

1. Permission of the sub-divisional officer is first obtained for the transfer.

2. Cross indents duly signed by both the contractors are then forwarded to the stores through the sub-divisional officer who will endorse both on the indent and invoice "transfer was permitted by me."

In the indent the following informations are noted.

a. Full details of the materials transferred with correct nomenclature.

b. Date of transfer.

c. A declaration by the receiving contractor that the materials have been handed over to him in good condition and that he is responsible to the stores for their safe return.

If the pumps or moulds are to be shifted by a contractor from one work to another, either in the same or other sub-division (*i.e.*, within the jurisdiction and possession), there is no necessity to obtain any permission for doing so.

Depreciation on Pumps and Moulds

Rent is charged for the period the government materials are under the charge of the contractors irrespective of whether these are used on works or kept idle. However the contractors are advised that when these are not needed, they should be returned to stores at their cost or transferred to any other contractor with permission of the competent authority as already mentioned above.

Statement showing the Details

Name of pump or mould	B.H.P. of engine	Capacity of pump in gallons per hour	Rubber Delivery Hose		Rubber Suction Hose	
			Dia	Length	Dia.	Length
Ford pump	20′ to 32′	19,200	3″	50′	4″	5′
Lister pump . ..	3′	1,500	1½″	50′	2″	5′
Deutz pump	3½′	3,000	2″	30′	2″	5′
Hamsworthy pump ..	4′	7,200	2½″	30′	3″	5′
7′ Hexagonal or Pentagonal mould . ..		.	.		.	.
4′ Hexagonal or Pentagonal Mould		.		..	.	..

Details of different kinds of pumps and the depreciation charged on them are given in the statement below.

On account of increase in rate of raw materials, the cost of mould has increased and consequently the rent for a 4 feet

mould including that of the tie rods is increased to Rs. 6 per set from September 1941. The contractors should note that when a set is returned to stores for repairs, etc., it should accompany all component parts; otherwise the new parts will be replaced and the cost debited to the contractor at

i. Tie rod for 4 feet mould at Rs. 12-9-9 per set.

M. S. pins for moulds at Re. 1-0-0 per set.

of Pumps and Moulds.

G. I. suction pipe		Total head in feet	Foot valves Dia	No	Rent for the pump with Acc: in col. 4 to 7 per month	Rent for additional accessories per mensum			
Dia.	Length					Rubber delivery per 25 feet	Rubber suction per running foot	G. I. Suction pipe per running foot	Each foot valve
4″	23′	100	4″	1	55 0 0	4 5 0	0 4 6	0 0 6	0 6 0
2″	10′		2″	1	21 0 0	2 0 0	0 3 0	0 0 4	0 2 0
2″	15′	100	2″	1	14 0 0	0 2 0 per Rft.	0 3 0	0 0 3	.
3″	12′	50	3″	1	15 0 0	2 0 0	0 3 0	0 0 4	0 2 0
..	..	.	..		6 0 0	..	..	..	..
..	..	..	.		4 4 0	.	.	.	

iii. M. S. clamp for mould at Re. 0-4-6 each.

iv. M. S. bolts and nuts at Re. 0-8-0 per pound.

In order to get at extra efficiency in the execution of work, the executive staffs are induced to understand the principles of the working of the pump and the engine, by discussion with the mechanical engineer as well as by practice, so that, when necessity arises, they may be in a position to start or stop the pumps or to render help and advice in effecting minor repairs to them.

A statement showing the cost of different stock articles available in the departmental head stores for use in the construction of wells in addition to stocking of cement, explosives, pumps, moulds etc., is given below.

Serial No.	Name of articles	Unit	Cost at stores	Remarks
1	Gelatine dynamite P.A. ..	1 lb.	1 12 0	
2	Blasting gelatine	do	1 14 0	
3	Detonators (Ordinary) ..	100	5 14 0	
4	do (Electric) ..	100	40 13 0	
5	do (Delay action) ..	Each coil.	0 8 6	
6	Black fuse (Swastik brand) ..	24 ft.	0 4 6	
7	do (Gutta-percha) ..	do	1 4 0	
8	Petrol	Gallon	1 13 2	
9	Kerosene oil	do	0 15 6	
10	Mobiloil (Engine) ..	do	1 9 8	
11	Grease (3F Shell)	do	0 7 0	
12	do (black)	do	0 7 11	
13	Cotton waste .. .	do	0 3 10	
14	Steel jumpers .. .	do	0 4 0	
15	Cement .. .	Bag.	3 0 0	
16	Pulleys (Small type) ..	Each	11 12 0	
17	do (Big type) ..	do	11 2 3	
18	Number plate	do	0 11 0	
19	¼″ reinforcement including fabricating . .	Cwt.	19 4 0	
20	2″ W.I. Downtake pipe ..	R.ft.	0 6 9	
21	Iron steps .. .	Each	0 8 0	

The above rates are subject to fluctuation without notice corresponding to market rates.

Ten per cent (10%) supervision charges will be added to these rates, when the articles are taken on sale.

As pumps are first started on petrol and then run on kerosene these materials are also stocked and issued to contractors as required by them.

PART IV

CHAPTER I

Recovery of Groundwater

Well Sinking

General considerations.

Various methods are employed in the recovery of groundwater, depending upon depth, quantity and the nature of water bearing rocks. Shallow wells form the means by which the groundwater very near the surface is obtained. Open draw wells even of 100 feet depth should be preferred to tube-wells for village drinking water supply due to the inherent disadvantages of the latter which are so obvious. In cases beyond these depths, where open draw wells cannot be excavated, the only means of recovering such deep seated groundwater would be by drilled wells. In certain places near hill sides (*e.g.* Aurangabad ancient water supply page 34) the groundwater can be recovered by means of horizontal tunnels or galleries, by lateral tunnels run into their sides to increase recuperation. The under-flow of rivers or big nalas may be brought to the surface by sub-surface dams. The construction of such dams across rivers or big nalas should be carefully thought out beforehand in relation to the type and nature of water available in the area. For instance, in the Raichur district where the inherent salinity in some type of particular rocks is a common feature, the construction of dams in such places effectively arrests the sub-surface flow of waters by conserving them under the accumulated silts, sands and underlying porous rocks to result in better yields and sweeter water in the wells near them.

The choice of open well and the bore-well sites depend upon topography, geological conditions of the underlying rocks, and other surface features, rainfall, climate etc.; all these have been dealt with in detail in the foregoing chapters.

Well logs

The maintenance of well logs is one of great importance, and each well sunk in the area by this department is subject to such records in the following manner:—

1. Place and position of well including wherever possible the M.S.L. of the mouth of the well.

2. Topographical features round the well.

3. Nature and thickness of surface soil.

4. Nature and thickness and the succeeding depths at which different types of rocks are met with in the well.

5. Total depth of well.

6. Depth at which water was first struck, its nature, amount, etc.

7. Depths at which subsequent springs were met with during the course of sinking, with notes on them.

8. Maximum depth of water after the well is fully sunk.

9. Nature and thickness of aquiferous beds, with other important details, which may or may not have a bearing on other wells, but may be more useful in the elucidation of the relation between the successful and unsuccessful wells in the area.

10. Recuperation of water at different depths. The method by which this recuperation test is carried out is given in detail elsewhere.

11. Quality of water.

12. Any other important details.

13. Besides the above, the depth of water in the completed wells is noted during three successive summer seasons.

Fluctuations in water level in wells have already been discussed.

Mutual interference of wells.

The spacing of wells in cases where large supplies of water are needed for either industrial or commercial purposes from more than one source has to be considered when dealing with rocks of different geological formations. Usually in gneisses, it is not possible to exactly forecast the extent to which such interference is likely to occur, due to the different sets of water bearing joints and fissures met with in them, but however, in cases of sedimentary deposits where water is tapped in different wells having the same water bearing stratum and in the Deccan traps where a definite moorum-like aquiferous bed yielding water in wells, this question takes an important bearing and has to be carefully considered in spacing the different wells in the area. Two or more wells situated close to one another deriv-

ing water from the same aquiferous bed would, by their simultaneous operation of pumping, yield less water than when they are made to operate individually. This interference depends upon the distance from well to well, the amount of water that is lowered by pumping, and upon the nature of the water bearing stratum. When water is being lowered to depths of 10 feet or more at a time, it would be preferable, in order to avoid too much interference, to space them beyond 200 to 400 feet. If the spacing is too small, the yield is likely to be less by 50 per cent than when they are placed farther away.

Design of wells.

When the work was first started in the Raichur district, the coursed rubble steining (C.R.S.) masonry of 6, 8 and 10 feet diameters were employed in wells but as the work progressed, it was found very difficult to maintain this sort of steining due to so many attāndant and inherent handicaps in the way. In many cases quarries being situated far away necessitated heavy expenditure by way of lead. During the construction of steining in wells, trained masons had to be employed at each well, who were mostly imported from some commercial or industrial centres at exorbitant rates. Lime was often obtained with some difficulty from some place or other, and the running of a mill for making lime mortar at every site entailed in great cost. In order to overcome these difficulties and to economise the expense on this head, mass cement concrete lining was introduced which proved most economical and was found very easy to construct even in wells situated in remote places. A rough comparative estimate of lining a well with 4 feet pentagonal mass cement concrete steining or with coursed rubble stone masonry is shown side by side to bring out the vast difference in cost between the two types.

Particulars	Per foot in height	
	4′ pentagonal C.C. lining 6″ thick & 1 : 3 : 6 proportion	C.R.S. steining 1′-6″ thick and 6″ internal diameter at an average rate of Rs. 50 per 100 cubic feet
Quantity ..	10.9 Cubic ft.	35·33 Cubic ft.
Cost O.S. Rs. ..	9 12 10	14 2 0

Therefore the difference in cost per foot height of lining is (14-2-0)—(9-12-10)=4-5-2 which works out to 44 per cent excess in the case of C.R.S. masonry as compared with C. C. lining.

The circular mass cement concrete linings adopted in the beginning proved later on, uneconomical and impracticable, as it entailed stocking of a number of different sized moulds for each type of well, besides the difficulty in maintaining the circular form, due to rough handling and conveyance in country carts over rough tracks of long distances from place to place. This was overcome by introducing pentagonal designs which requiring mere plates of sizes, were not subjected to any deformation while handling or conveying. After going through these courses of evolution, the standard designs that are now being adopted according to the needs of the population or demand are as follows :

I. Hexagonal wells of 4 feet inner and 4 feet 7 inches outer sides, thickness of lining being 6 inches, provided usually for a population between 500 and 800, with a maximum allowance for 6 pulleys. (This design is now mostly replaced by 4 feet pentagonal lined wells).

II. Pentagonal wells of 4 feet inner and and 4 feet $8\frac{2}{3}$ inches outer sides, thickness of lining being 6 inches provided usually for a population not exceeding 500 with a maximum allowance for 5 pulleys.

III. Hexagonal wells of 7 feet inner and 7 feet 10 inches outer sides, thickness of lining being 9 inches provided usually for a population between 1,000 and 1,500, with a maximum allowance of 12 pulleys.

IV. Pentagonal wells of 7 feet inner and 8 feet 1 inch outer sides, thickness of lining being 9 inches, provided usually for a population between 800 and 1,000, with a maximum allowance for 10 pulleys.

V. Septagonal wells are also constructed in rare circumstances with 4 feet inner and 4 feet 7 inches outer sides, with a maximum allowance of 7 pulleys, thickness of lining being 7 inches in cases where the population does not warrant the construction of 7 feet hexagonal or pentagonal wells, on account of their high costs, and where 4 feet hexagonal or pentagonal wells do not suffice the needs of the population.

Usually in almost every case the type designs No. 1 or 2 are provided, Nos. 3 and 4 being adopted where irrigation step wells are to be remodelled into irrigation draw wells, pulleys being fixed on all sides except on one side on which allowance for the construction of mhots are made.

Details are shown in the enclosed copies of the designs appendix.

Excavation

Wells are marked out according to the standard designs that are to be adopted as mentioned above, and excavation in circular forms is done according to the following diameters.

Type of well	Dia. for sinking in soft soil	Dia. for sinking in hard soil & soft rock	Dia. for sinking in hard rock	Remarks
4ft. hexagon ..	12′	10′	10′	No ledge is left on hard rock for constructional difficulties.
4 ft. pentagon ..	11′	(9) 10′	(9) 10′	do
4ft. septagon ..	14′	12′	12′	do
7 ft. hexagon ..	18½′	16½′	11½′	Ledge to be left on hard rock.
7 ft. pentagon ..	16′	14′	(9) 10′	do

It is seen from the above that lining is started from the bottom of the excavation in case of 4 feet hexagonal, pentagonal and septagonal wells, whereas in case of 7 feet hexagonal or pentagonal wells, ledges are left as soon as hard rocks are met with and linings are built on these ledges.

In cases where the soils are loose or the sides collapse, standard diameters cannot be maintained, and on being referred to the Special Officer, widening or sloping of the sides respectively are ordered to be undertaken as per details given elsewhere.

Excavation for 4 feet pentagonal wells is now done in diameters of 10 feet as against previous standard diameter of 9 feet (shown within brackets in the above table) where only $2\frac{1}{2}$ inches space were available for workmen, which are rather insufficient for them to work on.

While excavation is in progess, payment is made only in 9 feet diameter, and for the increased diameter of 10 feet payment is made only after the cement concrete lining is started. This would create an inducement in the contractors to complete the work as quickly as possible and in case the work is suspended or stopped, the subsequent contractor who may take up this work will have sufficient margin to cover the extra cost incurred by him in dressing the sides, etc.

Similarly in wells which are abandoned excavation is paid only for 9 feet diameter.

Diameter of excavation below the ledge for 7 feet hexagonal or 7 feet pentagonal wells or circular masonry well

I. In cases where excavation from the top is started for a 7 feet pentagonal well, the diameter below the ledge should be 9 feet,

and

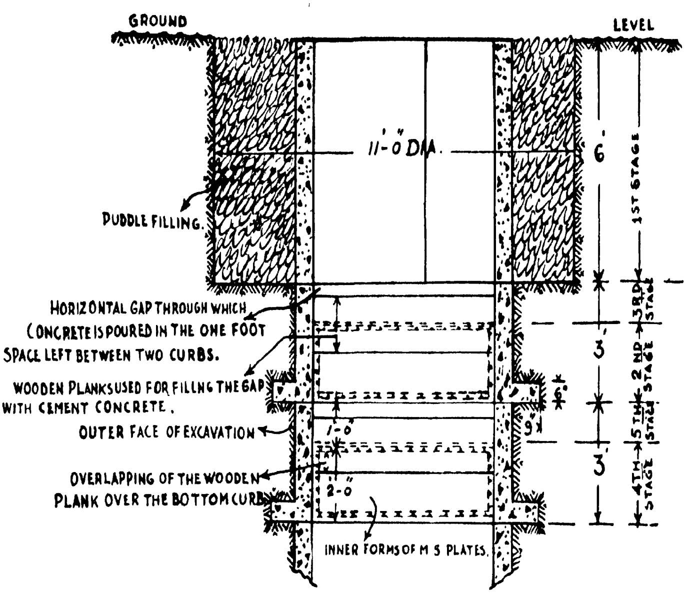
II. If wells originally excavated for 4 feet pentagon are due to great depths subsequently lined as 7 feet pentagon or are steined in C.R.S. masonry for a few feet at the top, the diameter below the ledge should be according to the actual measurements subject to a maximum of 9 feet 9 inches.

For the portion of excavation above the ledge W.S.D. rates are paid in 10 feet diameter and for the rest which goes under widening at the P.W.D. well sinking rates.

Excavation is done by the aid of picks, crowbars and powrahs and the materials hauled up on head loads, so long as the excavation progresses within the soils. The verticality of the well can be maintained by the use of plumb-bob and the diameter by the aid of bars or cross-bars. This method of sinking becomes practicable in cases where the loose soil does not extend to great depths, but in cases of great depths, the excavation has to be conducted by stages. This method consists in making a wide shallow excavation with sloping sides of $1\frac{1}{2}$: 1 or 1 : 1 according to the nature of the

REVERSE METHOD OF LINING (FROM TOP TO BOTTOM)

(TO BE ADOPTED FOR SINKING WELLS IN THICK MANTLES OF SOFT SOIL)



SECTION OF WELL.

EXPLANATION.

1ST STAGE :– SINK IN 11 FEET DIAMETER TO 6 FEET DEPTH, AND BUILD C.C. LINING. FILL THE BACK OF LINING WITH PUDDLE.

2ND AND SUCCESSIVE STAGES – SINK FURTHER BY 3 FEET, SIZE TO BE IN CONFORMITY WITH THE OUTER FACE OF C.C. LINING, AND MAKE A GROOVE 6" x 9" AT BOTTOM ALL ROUND USING INNER FORMS ONLY, LAY ONE CURB OF C.C. LINING OF 2 FEET HEIGHT, AND ALSO FILL THE GROOVE. THE ONE FOOT GAP BETWEEN THE TWO CURBS, SHOULD NOW BE FILLED BY USING PLANKS, THE CONCRETE BEING PUSHED FROM TOP AND SIDES.

soil. On the floor of this, further excavation of similar size is done until firm rock is reached as shown below:

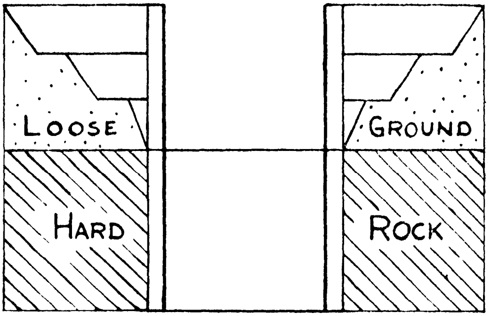


FIG. 16. *Method of excavation in loose ground.*

In this way the temporary lining in the course of sinking is dispensed with and the usual lining of the well is started from the ledge or from the bottom of the well itself in conformity with the methods laid down by the department.

Reverse method

In order to save huge sums of money on widening in soft and clayey soils where these extend to great depths the '*reverse method*' of lining is adopted for the introduction of which the author is responsible. It sometimes so happens, while sinking that even in hard soil caving and collapsing of sides occur which, besides proving dangerous, entails heavy widening of the section. In order to overcome these features open excavation 11 feet in diameter, is done to a depth of 6 feet. At the bottom of the excavation reinforced cement concrete lining of 1 : 2 : 4 proportion of 6 inches thick is built with the help of 2 feet high moulds to a height of 6 feet. Twenty-four hours after the last 2 feet high reinforced cement concrete curb is laid, the space between the lining and the cutting is filled with "*puddled*" clay to hold the curbs in their places. This is allowed to set for a day. Then further sinking to another 3 feet with sides flush, with the outer face of the overhanging curb, is done, and a groove 6 to 9 inches is cut at the bottom all round. The inner forms of the mould are put in position at the bottom and 2 feet high reinforced cement concrete lining constructed from the new bed of the well and the groove is also filled to give added strength to the curbs from slipping down. This would leave a one foot gap all round between the overhanging and the newly laid bottom

curbs which is then filled up by using planks and the concrete pushed from top and the sides. The process of 3 feet excavation is thus continued and lining done until the required depth is reached. It may be noted that the thickness of the curbs, other than the 6 feet top one, would be more or less 6 inches, depending upon the evenness of excavation of the sides below the initial top lining. But every effort is made to keep these sides as flush as possible to conform to 6 inches thick of subsequent lining. The excavated sides form part of the outer mould of the subsequent lining and therefore no outer moulds are used.

In case where hard material which may form a safe ledge is anticipated to be encountered and below which depth excavation is not possible to be done in a confined space of 5 to 6 feet diameters, the lining from the top is done in 7 feet pentagon in the same manner as described above leaving a ledge, below which open sinking to 9 feet diameter is conducted in the usual manner.

In such cases of lining, if water is encountered through strong individual springs at the sides, then vertical grooves are cut in them, which are then covered with planks connecting them up to a sump at the bottom. This water is from time to time bailed out.

Curb sinking.

In cases where unconsolidated sand, soil or friable rock is met with, curb sinking is adopted. The first reinforced cement concrete curb of 1 : 2 : 4 proportion of 2 feet high is cast on the ground with a cutting edge of wood or iron at the bottom to facilitate the downward movement. Over this first curb, another 2 feet curb is laid and over it a third one of 2 feet high, making in all a total of 6 feet high. These are well cured for a period of more than one week, and then the excavation of the earth beneath the curb is evenly conducted, while the curb simultaneously goes on sinking by its weight. Sometimes it becomes necessary to add weights in the shape of sand bags etc., over the curb to maintain it in motion or to restore it to a vertical position. Even a slight departure from its vertical position will cause strains in the curb and may break them ; and when once this happens it becomes difficult to set it again moving. When the curbs are lowered by about five feet, further curbs should be cast, and sinking conducted. Vertical reinforcement is introduced between two successive curbs as it sometimes happens that the resistance to sinking gets so great, particularly if sticky material gets in between the lining and the

soil, that the curb will not sink even when all the earth immediately beneath the curb has been removed. When this happens, the curb is so to say, suspended with no support except the tenacity of the mortar, and at this stage unless two successive curbs have been joined together with proper reinforcement in the manner mentioned above there is danger of the curb detaching from the lower part or that the lower part may crack off from the upper. The curbs are therefore, to be heavily weighed during sinking to overcome the frictional resistance between the curb and the soil thus lightening the labour of sinking.

The frictional resistance to sinking increases with depth as long as the lining makes a close fit with the enclosing ground. The well should be kept continuously sinking to avoid any outside material getting into the well. A light well dropping only at intervals would therefore necessitate greater amount of earth to be dredged out than a heavy well continuously sinking and thereby preventing outside material from flowing into the well.

Sinking can be continued below water level by dewatering the wells by means of mhots or power pumps according to the exigency of the situation. After sinking is completed to the required depth, and if no solid rock be encountered at the bottom, it is found advisable to pitch the bed with boulders and tamp them so that they may settle solidly and prevent the linings above from further sinking.

The rates for excavation of soils in different districts and sometimes in taluqs of the same district under the agreement bond are given in pages 139 to 154.

The rate for sinking in dry and wet soils include the cost of arrangement to be made by the contractor for the removal of muck and bailing out water ; as such payments are not made for construction of mhot walls. To avoid accidents, etc., strong mhot walls are to be constructed as detailed elsewhere.

Classification of Soils

Classification of soils are as a rule done by the sub-divisional officers, but if, for any unavoidable circumstances, it is not possible for the sub-divisional officer to attend to it by himself and payments have to be made in the meanwhile, the sectional officer may give a tentative classification which, of course, is to be check measured by the sub-divisional officer before lining is started.

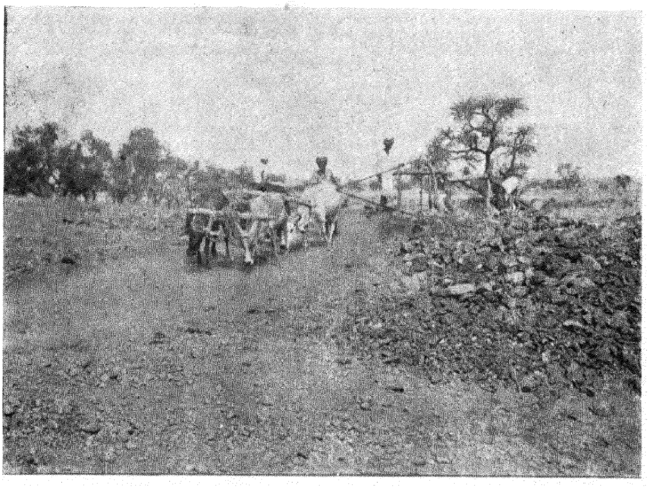


PHOTO PLATE NO. 8.— *A well under excavation showing the mhot drawn by bulls for bailing water from the well.*

Claims for higher classification received from contractors, after the lining has either been started or completed and the space behind the lining is filled up, cannot be entertained as such claims cannot be disposed of due to the impossibility of reclassification under the obvious position mentioned above. In order to avoid such situations, contractors will have to put up in writing such claims for classification while sinking is in progress or before lining is started.

The method of classification of rock found mixed with hard or other soils on the basis of percentage judged by the eye is not correct and is likely to be misleading. Hard rock is therefore to be stacked to a depth of not less than 2 feet and voids ranging from 40 per cent and above are deducted. When excavation or deepening is done entirely in rock the excavated material need not be stacked as it is paid on the dimensions of the well.

But in consequence of the change in sinking rates for every 5 feet depth, the method of giving measurement by stack for hard rock has been slightly modified as it is not practicable to stack hard rock separately for every 5 feet depth. The hard rock is stacked as usual, but percentage of hard rock for various stages of 5 feet depth in the portion where hard rocks are met with or not is given to arrive at the aggregate quantity of the stacks.

Classification of Shale and Shahbad

A uniform classification of soft rock and hard rocks is allowed for shale and Shahbad stones. But if the top strata is found softer than the bottom layers, the classification will be reduced from the one mentioned above. On the other hand if concretions are found in abundance in between the layers of these strata, the classification is increased to hard and soft rocks.

Excavation in Rock

Blasting.

When rock is encountered, the sinking cannot progress except by blasting. Under such cases, the spacing and the disposition of the blast holes have to be carefully considered in relation to the nature and type of rock that is encountered to get the maximum disruptive effect by blasting. Usually the rock surface presented at the time when the rock is encountered in a well, would be almost horizontal and devoid of any other faces to take advantage by blasting. Under such cases the following considerations may be found useful.

I. The form of cavity produced when a single drill hole is fixed in a mass of rock having one free face (horizontal face) is usually that of a cone. Thus in figure below if a, b, represents a vertical drill hole, the rock broken will theoretically have the form c, b, d the line c, d, being the diameter of the base of a cone. If the strength of the explosive is not

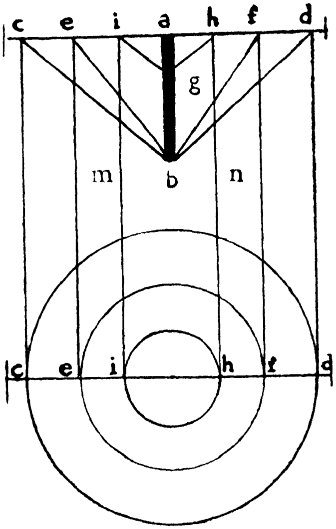


FIG. 17.

sufficient to overcome the tenacity of the rock to the extent that is represented, the cone might take the form e, b, for i, g, h. It is more than likely that a blast hole put up perpendicular to such a face will break no rock at all, and may result in a blown out shot, as it is the worst position to do any effective work. This is because any pressure exerted at the sides 'm' and 'n' is opposed by the resistance of an indefinite thickness of rock, and the line of least resistance along which the force of the explosive naturally acts, will be the resultant of the forces acting on 'm' and 'n' or the line of the blast hole itself.

Taking the disposition of a blast hole a, b to be inclined to the face as shown in the diagram below, the line of least resistance e, b being perpendicular to the face, the cross section of the piece of rock broken out will be approximately

in the form of a, b, c and rarely that of d, b, c. Commonly one edge will coincide with the blast hole and the other will be betwe?n the lines e, b and c, d. The angle e, a, b should usually b: about 35 degrees for the best results, with 45 degrees as its limit Less will be the rock broken as the angle

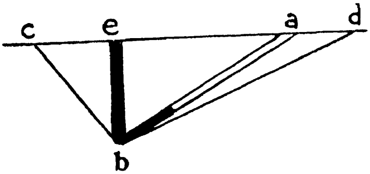


FIG. 18.

becones less and when the direction of the blast hole a, b is thesame as that of the free face a, c, *i.e.*, when the powder is paced on the top of the face, no rock will be broken out. Similarly as the drill hole becomes more nearly perpndicular less will be the volume of the rock broken and whe the hole is vertical as e, b, it will, in very majority of cses result in a blown out shot.

n case where the rocks present some free faces the situatior is improved, and a cross-section showing a hole a, b, plaed in a rock having two free faces C and D may now be onsidered. With only the free face C the charge at b

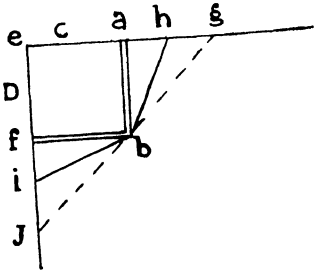


FIG. 19

wild break out the crator e, b, g and with only the free fa at D the charge at b, would similarly break out the crater e,', j. But with the charge at b, equidistant from the two fas C and D and of just the right size the bounding surface olhe two craters, would coincide with the line b, e, but sie the force of explosion at b is divided between the two crers and a portion of it is reflected by the solid rock, the

crater actually broken out will be approximately h, b, i, and not that which is equal to the sum of the two craters e, b, g and e, b, j.

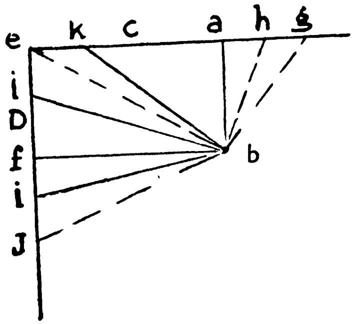


FIG. 20.

When the charge b, is put up in such a way that b, ˙, is greater than b, a, the force acting on each face will breakthe cones g, b, k, and j, b, l, the wedge shaped piece e, k, l, l, not being included in either, but with the charge b actingon both faces C and D together, part of the force is utilisecin breaking up the mass e, k, b l, resulting in the crater h, , i instead of g, b, j.

Similarly such reasonings may be applied to any numer of free faces that are present, and may be utilised to bst advantage. It follows therefore that the greater the nu-ber of free faces, the grater will be the amount of mateal that can be broken out, which amounts to a smaller chare doing the same work with the greater number of free fa(s but not necessarily proportionate with the increasd number of free faces.

There seems to be a general rule that the longest linef resistance should not exceed three halves of the shortest li: of least resistance, *i-e.*, 3 : 2 if the maximum effect of t: explosives is to be obtained. If possible the shots should : placed so that the shortest line of resistance is horizonl and the longest vertical so that the weight of the rock m' assist the breaking down.

From the foregoing remarks it becomes clear that it advantageous to obtain as many free faces as possible blasting not only to reduce and economise the charge b also to get the maximum amount of material disrupted.

In cases where rocks with one horizontal face is obtained, the usual procedure adopted is to drill two or more holes so arranged and inclined as to almost meet at their lower ends. After blasting these holes, the subsequent holes are arranged

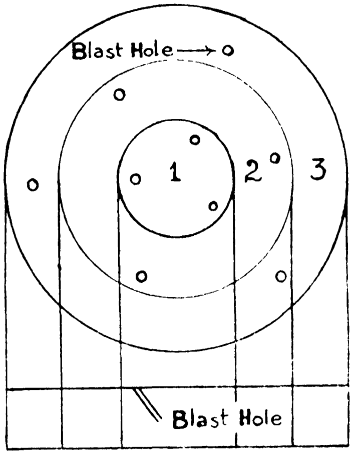


FIG: 21.

in the manner shown in the second circle, and after these are blasted, the other holes are arranged as shown in the third circle and so on. The diameter of the hole is kept at one inch to exactly press down the $\frac{7}{8}$ inch cartridges stocked by the department. The depth of the hole ranging from 1 to 1½ feet.

Drilling holes by jumpers & boring bars or steel

These are of steel of 5 feet 6 inches to 7 feet long with chisel shaped points at both ends, slightly wider than the diameter of the bar. Holes of 1 inch diameter are made by lifting and dropping the rods respectively. These are used for vertical or nearly vertical holes, but when slanting holes are to be drilled, the boring bars of octagonal steel of 3 feet 6 inches to 4 feet long, having chisel points at one end only are used. This bar is held in an inclined position by one man who on each blow on its head by a second man, twists it slightly and the process continued. The sludge is usually removed by improvised brushes made by beating the ends of some fibrous wood available nearby to which the powder clings and which is then withdrawn.

The holes are then charged with cartridges of dynamite, by blasters holding the necessary licenses, which give complete instructions. The form of license issued is as follows:

Charging holes for blasting.

H.E.H. THE NIZAM'S WELL SINKING DEPT.

No.................... Blasting License..... ....

Name of blaster..........................

Father's name....................

Age..........................Village................

Taluq....................District..................

Caste........................Identification mark.... ..

Name of Employer.........................

After satisfying myself that the above named person is conversant with the methods of blasting and knows how to deal with misfired holes, I hereby authorise him to conduct blasting operations during excavation of wells.

I certify that the instructions printed on pages 3 to 10 have been translated and explained to the licensee in his vernacular and that he fully understands them and undertakes full responsibility of the consequences of the accidents occurring due to defiance of these instructions; in token thereof he attests it by his signature/thumb impression, in the presence of his employer.

Sectional Officer,

Date................

Contractor.

Blaster.....................

On enquiry and verification I find the above to be a correct statement.

Date...................... *Mechanical Engineer.*

Important Instructions for conducting Blasting Operations (pages 3 to 10 of license)

Storage.

I. Explosives should always be stored in a perfectly dry and water-tight locked shed or store house. Detonators and safety fuse should be stored in separate compartments or in separate sheds, under lock and key.

II. The storing place should never be a dwelling place.

III. Detonators should never be kept along with high explosives.

IV. Explosives and detonators should not be exposed to rain or to the direct heat of the sun's rays.

V. Do not place explosives near fires, stores, steam pipes, heated bodies, etc.

VI. Do not use nitro-glycerine explosives which are in a chilled or frozen condition. Such cartridges must be softened before use.

Connecting Safety Fuse to the Detonator.

1. Shake all the saw-dust carefully out of the detonator.

2. Cut the safety fuse straight across, with a sharp knife, which should be kept clean. Be sure to use a freshly cut end of fuse for insertion into the detonator. Do not let the ends of the fuse get damp.

3. The fuse should be sufficiently long to allow the blaster after igniting to go to a safe distance, and in order that the charges should fire at different intervals the fuses should be of different length.

4. Every blaster must carry a knife to cut a burning fuse when necessary and an approved detonator nipper, for crimping the detonator on to the fuse. He shall not have in his possession any iron or steel picker, scraper, tamping rod or stemmer, and only clay or other non-inflamable sustances should be used for tamping or stemming.

5. Slip the detonator over the end of the fuse until the composition and the fuse are in contact. Never screw the fuse against the composition.

6. Crimp the detonator gently, but securely on to the fuse with the approved detonator nipper. Take care not to break the powder core of the fuse by pinching too tightly.

III. *Preparing the primer*

1. The fuse and detonator shall not be inserted in the primer cartridge until it is required for immediate use.

2. Open a cartridge at one end and make a hole with a small stick in the opened out end and push the detonator into the hole leaving one-third of it projecting.

3. Tie the cartridge paper firmly round the detonator.

IV. *Charging the hole*

1. It is preferable that blasting operations are carried out either at midday, luncheon hour or at the close of the work.

2. Clean out the bore-hole, insert the cartridges one at a time and squeeze each home gently with a wooden rod and never with a metal one. Do not ram, pound, bunch or double up the cartridge into the hole, but gently press down so as to form proper contact with the sides of the rock. No explosive shall be forcibly pressed into a hole of insufficient size.

3. Avoid the practice which is sometimes adopted in inserting the primer cartridge first or in the middle of the charge. This method of '*inverse initiation*' is unsound as the force of the explosion travels in the opposite direction to that required and may give rise to blown out shots. Lower or push the primer cartridge gently into the hole until it rests against the charge. The primer cartridge should be inserted last.

4. A wad or paper of sufficient quantity to form 1 inch thickness in the hole when pressed home, should be inserted.

5. Tamp with sand or clay, putting several inches loosely and then ram hard.

6. Before igniting the fuse, the workman and others should be warned not to be within 200 yards and efficient arrangements should be made for the blaster to get out of the well easily.

7. The number of blasts fired and the number of shots heard will have to be counted, and unless these two tally, nobody should approach the scene until half an hour or preferably one hour has elapsed.

8. During charging, all lights must be kept at a safe distance and smoking should be strictly prohibited while handling explosives.

9. Blasting gelatine or other high explosives shall not be lighted in order to set fire to fuses, but a small portion of such explosive may be attached to the end of a fuse to assist it to ignite.

10. Before any shots are fired all approaches to the place where the shots are being fired shall be guarded. The blaster shall be responsible that no person is allowed to remain in or come into dangerous proximity to the shots.

11. The number of shots which explode must be counted by at least two persons, one of whom shall be the blaster. Unless both are certain that all the charges have exploded the working place must not be re-entered for at least one hour after the last explosion.

12. If all charges have exploded properly the working place should be re-entered as soon at it is sufficiently clear of fumes. No one should get into the well till the smoke completely disappears ; and as a further precaution a few buckets of water should be splashed down the well before getting in.

13. After blasting has taken place, the blaster or person in charge of the working place shall be the first to re-enter and until he has pronounced it to be safe and sufficiently free from fumes, he shall not permit any other person to enter, except for the purpose of making it safe.

14. In clearing the stuff broken by the blast, loose unexploded cartridges, detonators, etc., must be carefully looked for and if found, removed at once by the blaster or maistry in charge, to a safe place.

V. *Misfires*

1. If a misfire occurs the mud plugs should be removed up to the top of the wad of paper and nothing further.

2. A fresh charge should then be put on the top of the old charge and blasted.

3. On no account should the detonator be removed from the primer cartridge.

4. A copper rod should be used for scooping the mud, etc., and never an iron one.

5. If the misfire cannot be found, further work should be stopped and the matter reported to the sectional officer. The blaster shall before leaving the site, fix a red flag in the well and inform the maistry in charge, if he is present if

not, he should post a man to prevent access thereto and warn persons of the existence of misfire. He should also put a red flag outside the well cautioning people not to come near the well.

6. The maistry in charge of the work may have the place cleaned up and made secure, but no drilling shall be permitted until the misfire has been reblasted.

Every misfire should be noted in the 'remarks' column of the register of explosives account kept at site.

7. No portion of a charge shall be withdrawn from a hole either before or after blasting. The deepening of or tampering with holes in which explosives have once been charged is strictly prohibited.

8. The blaster in charge of the working place, shall point out the position and direction of every new hole to be drilled, and shall be responsible that the drillers do not deviate therefrom. Greatest care shall be taken that no new hole shall be bored in such a direction that it can come in dangerous proximity to any old hole or socket in which explosives have previously been charged. No hole shall be bored at a distance of less than 12 inches from any hole where a charge has missed fire.

The amount of excavation of rock by blasting varies with different types of rocks encountered. In compact rock like the granitoid gneisses the disruptive effect of the dynamite will be comparatively greater as most of the energy is utilised in doing effective work. But in rocks with too many joints and cleavages, the amount of rock disrupted would naturally be lesser in comparison as some of the energy is lost along such joints and cleavage planes. Below is given the amounts of dynamites that were used in various geological formations to give an idea of the effective disruptive power of these explosives.

[*Statement.*

Data of explosives used in excavation of wells.

GEOLOGICAL FORMATION, *Deccan Trap.* PARENDA TALUQ.

AVERAGE PER FT. RUN OF EXCAVATION IN HARD ROCK IN 10′ DIAMETER OR 78.59 CU.FT.		MINIMUM PER FOOT RUN		MAXIMUM PER FOOT RUN		No. of wells over which average was worked
Dynamites	Detonators	Dynamites	Detonators	Dynamites	Detonators	
32	31	23	23	37	36	3
17	17	15	15	19	19	2
17	17	7	7	35	35	13
12	12	10	10	17	17	3
7	6	7	6	7	6	1
7	6	7	7	7	7	1
19	18	19	18	19	18	1
111	107	88	86	141	138	24

	Dyanamite	Detonator
Average in the taluq per foot run or for 78 59 Cu.Ft. of hard rock	16	15
do for 100 Cu. ft. in hard rock . .	20	20

GEOLOGICAL FORMATION, *Deccan Trap.* TULJAPUR TALUQ.

10	10	10	10	10	10	1
15	15	15	15	15	15	2
9	9	9	9	9	9	1
7	7	6	6	9	9	2
30	30	18	18	40	40	5
21	21	19	19	22	22	2
18	18	11	11	33	33	5
35	35	19	19	54	54	3
18	18	9	9	32	32	19
17	17	9	9	31	30	10
37	37	37	37	37	37	1
17	17	12	12	19	19	7
30	30	9	9	83	83	11
18	18	2	2	37	37	9
18	18	11	11	23	23	6
21	19	11	11	32	32	4
10	10	10	10	10	10	1
27	27	27	27	27	27	1
18	18	12	12	23	23	3

GEOLOGICAL FORMATION, *Deccan Trap.* TULJAPUR TALUQ.—(*contd.*)

AVERAGE PER FT. RUN OF EXCAVATION IN HARD ROCK IN 10' DIAMETER OR 78.59 CU.FT.		MINIMUM PER FOOT RUN		MAXIMUM PER FOOT RUN		No. of wells over which average was worked
Dynamites	Detonators	Dynamites	Detonators	Dynamites	Detonators	
11	10	2	2	23	23	3
22	19	22	19	22	19	1
23	23	23	23	26	26	2
26	26	26	26	26	26	2
21	18	21	18	21	18	1
7	7	6	6	9	9	2
486	477	356	350	703	666	104

	Dynamites	Detonators
Average in the taluq per ft. run or for 78.59 Cu.ft. of hard rock	19	19
do 100.00 Cu.ft. of hard rock	24.8	24.8

Similarly the average quantity of explosives used per running foot of excavation in 10 feet diameter (78.59 cubic feet) in limestones and shales works to:

	Limestones	*Shales*
Average per foot run or for 78.59 Cu. Ft. of rock: *Dynamites:*	13.3	21.9
do do for 100 Cu. Ft. of rock:	17.0	28.0

Percentage cost of explosives used to that of works during 1941 and 1942

It is observed that the percentage cost of explosives to that of total work done with and without cost of stock articles

such as cement, steel etc., supplied by the department is as follows :

Cost of the Explosives used during the year

1941

1.	20,692 lbs. of dynamites at O.S. Rs. 2-2-10 per lb. .. Rs. ..	45,048	3	4
2.	1,83,831 detonators @ 6-14-6 % ..	12,693	11	0
3.	57,447 lbs. of gunpowder @ 1-0-0 per lb. (inclusive of all charges). ..	57,447	0	0
4.	42,128 coils of fuse each of 24′ length at 0-13-2 per coil. ..	34,667	13	0
Add :—				
	10 % towards supervision charges on items 1, 2 & 4 as gunpowder is directly purchased by the contractors and not from the department :	9,240	15	7
		1,59,097	11	3
Add :—				
	5 % on items 1, 2 & 4 towards cartage to worksite from the departmental stores ..	4,620	7	9
	Total cost of explosives ..	1,63,718	3	0

Amount of Work done during the year

(*i*)	Excluding stock charges	5,31,293	0	0
(*ii*)	Including do	6,56,591	0	0

Percentage cost of explosives on (*i*) 30.81%.

Percentage cost of explosives on (*ii*)—24.93%

Cost of explosives used during the year 1942

1.	21,858 lbs. of dynamites @ O.S. Rs. 2-2-10 per lb.	47,586	11	0
2.	1,83,560 detonators at 6-14-6% ..	12,677	1	9
3.	57,362 lbs. of gunpowder at 1-0-0 per 16′ (inclusive of all charges). ..	57,362	0	0
4.	42,066 coils of fuse each of 24′ length at 0-13-2 per coil. ..	34,616	13	0

Add :—

10 % towards supervision charges on items 1, 2 & 4	9,488,	6	0

Add :—

5% towards carting to worksite on items 1, 2 & 4.	4,744	0	6
Total cost of explosives. ..	.1,66,474	11	3

Amount of work done during the year.

(*i*) Excluding stock charges...	..6,73,566	14	11
(*ii*) Including do ..	..7,47,258	9	9

Percentage cost of explosives on (*i*) 24·72%

Percentage cost of explosives on (*ii*) 22.27%

The average for the two years works out to:
With stock charges — 23·60%

Without stock charges :— 27·76%

NOTE.—On the average, the number of holes fired with gunpowder is 1¼ times that fired with dynamites and detonators.

The average length of fuse used per hole is 2 feet in the case of gunpowder, and 3 feet when dynamites and detonators are used.

(The data of explosives given above are mostly for works in *Deccan Trap* formation).

Caving of sides.

In the foregoing paragraphs on the geology of the Deccan traps, it was stated that beds of lithomarge like materials occur interbedded with harder rocks, consequently during excavation of these rocks it happens that when such soft friable beds are encountered, caving of the sides invariably occurs. In order to overcome the flow of material into the well, a masonry ring with weep holes at the bottom is constructed all round the caved portion, and further sinking is then conducted.

Fake masonry.

When the columnar or highly jointed rocks are encountered during excavation, some portions of such rocks slip down the sides and cause injury to men working in the well. Under such circum-

To face p. 208.

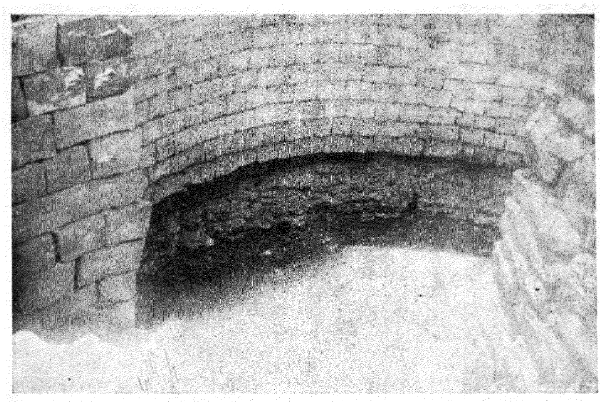


PHOTO PLATE NO. 9. *An old well with imperfect steining of non-technical design falling off at the lower portions where due to soft friable material caving of sides occur.*

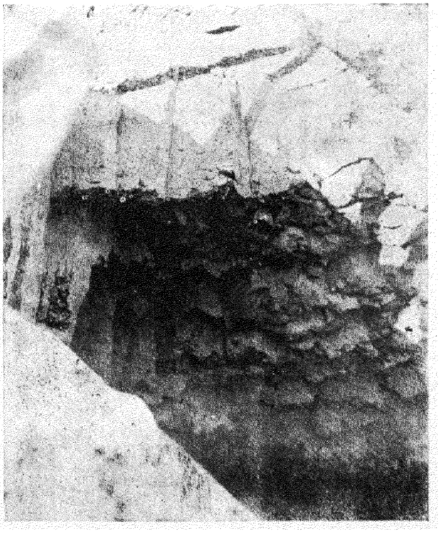
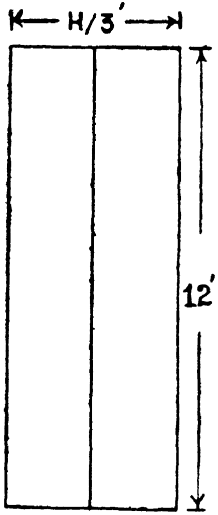
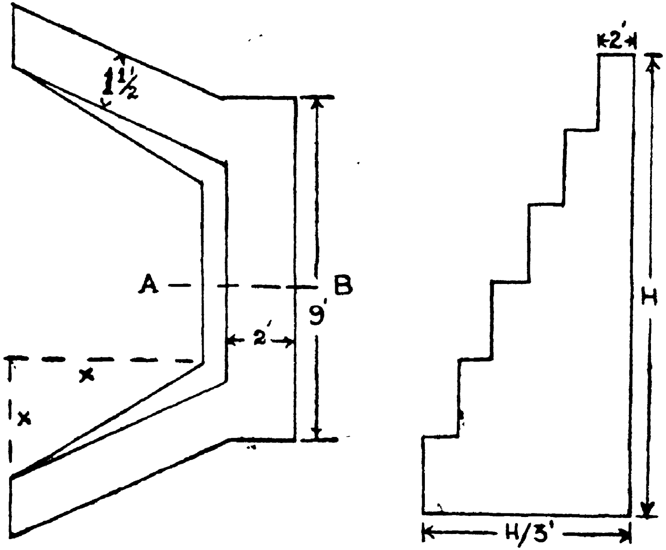


PHOTO PLATE NO. 10. *Section of the columnar jointed rock. These rocks though stable for all appearance still are most dangerous to found ledges on them due to their peculiar joints.*



PLAN

Where depth of soil does not exceed 5 feet



PLAN

Where depth of soft soil is more than 5 feet

stances, a type of masonry work introduced by the Author and named by him as '*Fake Masonry*' is adopted very successfully. In Parenda town and Bhonja village of Parenda taluq where such instances were met with, this method was not only very successfully adopted but, besides preventing accidents, saved much expense to the Government. This method consists of merely dabbing mortar and stone chips all round such rock faces, which after setting most effectively prevents for a considerable time loose and unbalanced stones from falling into the well. After this is done further sinking is continued without any further apprehension.

Hoisting or Haulage of Materials, etc.

The excavated rock materials, etc., are hauled to the surface by means of buckets run on mhots, which are of sound construction to avoid the danger of collapsing and causing accidents. The method of construction for different depths of soil is given below:

The above plans and section give the details of construction of foundations and basements on which the mhots are to be erected.

Mhot walls should be so built that they can stand against all possible disturbances, especially in cases where the depth of soft soil at the top is great. The following points are therefore to be observed.

1. If the depth of soft soil does not exceed five feet from ground-level, a dry rubble wall 2 feet thick will serve the purpose.

2. If the depth of the soil exceeds 5 feet from ground-level, pucca masonry wall, either with lime mortar or cement mortar in 1 : 12 proportion is built, the thickness of wall at any point being not less than one-third ($\frac{1}{3}$rd) of the depth at that point from the top of the wall, *i.e.*, if the height of the wall is 9 feet, the thickness of the wall at the bottom should not be less than 3 ft. ; and if 12 feet, it should be nothing less than 4 feet, etc.

3. Holes are left in the mhot wall to drain away the soaked water bailed out from the well so that it may not soak through.

4. The frame of the mhot is made of strong wood.

5. The axle of the pulley is to be of steel.

6. The ropes should be strong and should be tested. No worn out ropes are allowed to be kept at the worksite ; in fact such ropes are ordered to be destroyed at worksite by the inspecting officers of the Department.

Improvised mhot.

Sometimes an efficient improvised method of mhot construction is adopted, which consists in fixing upright palmyra trunks on the hard soil below, on top of which horizontal wooden beams are laid, whose ends away from the well face rest at least 5 feet on the ground from the sides. The diagram by the side clearly shows the way in which it is done. Zinc sheets are laid on the horizontal beams, to drain off the water raised to surface without washing or undermining the soil below them. This method has been successful, but the men in charge of such works are strictly warned to see that the stability of the structure is maintained at all times and that any slight defect that may arise be rectified immediately.

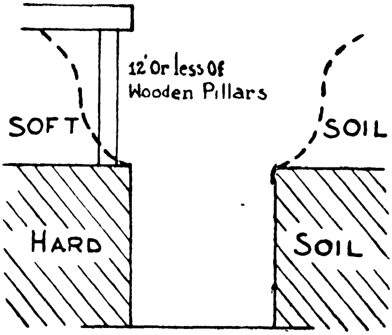


Fig. 22
Improvised Mhot

In cases where mhot walls are substituted a remark to this effect in measurement book is made by the sectional officer.

The excavated materials are thus hoisted out by letting down and drawing up the buckets by means of ropes on pulleys worked by men.

Sinking below water-level is done by bailing out the water by mhots or power-pumps either owned by or loaned to the contractors from the Department.

Power-pump & chamber.

When power-pumps are used for de-watering the well usually a pump chamber has to be excavated by the side of the well. The size of this chamber in hard strata is 5 feet by 5 feet. The depth to which the pump chamber has to be excavated depends upon the suction height of the pump and the depth to which the well is sunk. Usually the suction height of 3½ and 4 BHP Hamsworthy and Deutz pumps that are commonly employed by this

Department is 15 feet and the maximum depth of the pump chamber to be excavated would therefore be the difference between the total depth of the well and the suction height. In some cases 20 BHP Ford Pumps are used when the dimensions of the chamber at the base have to be made 5 feet by 6 feet with vertical sides up to the limit of soft soil above, where a footing of one foot width is left all round and then sloped off in the soft soil. The size of the chamber opposite the well is given a slope of 1 : 3 to facilitate the lowering of the pump.

Exhaust gases from power pumps.

If the pump chamber goes below 30 feet from ground-level, it then becomes necessary to conduct the exhaust gases to the surface by means of additional lengths of pipe to reach the surface. This would prevent accumulation of carbon-di-oxide and other heavy poisonous gases in the well. This precaution of leading the exhaust gases to the surface becomes equally important when power-pumps, instead of being placed in special chambers as mentioned above, are either slung or mounted on platforms supported by stanchions, directly into the wells. When the pump has worked within the well for a long time, it is necessary to see that before getting down the well, no noxious exhaust gases have accumulated, which might endanger the lives of the people. To satisfy this point a lighted candle may be let down the well to see if it burns or is put out; in the latter case buckets of water may be dashed into the well to force a draught to wash away the gases. In order to effectively de-water the well under excavation a sump sufficiently deep to cover the foot valve is excavated in the bed of the well when the water accumulates which is removed by the pump. The provision of such a sump greatly helps the progress of work by localising the water.

RECUPERATION TEST

Stopping of Sinking

The yield or recuperation of water in wells is a very important factor the correct working of which depends upon the success of the test. This test has also a direct bearing on the depths to which wells have to be sunk, to prove perennial sources of supply. The depth of water in a well is not the deciding factor but the (1) recuperative capacity of the well, and (2) the number of people to whom it is expected to sup-

ply water in the driest part of the year. Item No. 2 is a known figure and item No. 1 depends on several factors, *i.e*, the situation of the well in relation to the surface topography, nature of rocks and soil and the rainfall in the area, the depth below permanent water-level and the part of the year in which the well is sunk. In order to conduct a test, the normal one year period is divided into:

1. Recuperation period, *i.e.*, period in which the recuperation of the well is at its maximum and this roughly corresponds from August to end of November.

2. Period in which the recuperation of a well is normal or stationary, *i.e.*, neither at its maximum nor at its minimum and this period roughly corresponds from December to end of February.

3. Depletion period in which the recuperation is at its minimum, which corresponds from the end of March to July.

When sinking is carried out in a normal year of recuperation period, it has to be continued till sufficient recuperation of water to supply the population at 30 gallons per head per day is obtained and during depletion period at the rate of 20 gallons per head per day. This figure takes into consideration the number of domestic animals for which no separate provision is made. When this amount of water is obtained in a well it would be safe to stop further sinking and finish the lining, etc.

Method of taking recuperation test.

It is important that when taking this test the well should be heavily pumped for some time to remove any fine sand or silt that may be present and to establish the normal yield. The yield in wells is usually increased by first pumping particularly if the water-bearing beds contain sand or clay which may be removed by pumping. The minimum depth of water in a well is estimated to be 3 feet for a pot to be lowered into the water to completely fill it. Hence in calculating the recuperation test, this depth of water is omitted forming a reserve. The well is first completely emptied and the time noted, and then the time taken for the water to rise to 3 feet depth is noted. Similarly the time taken for the rise of water from 3 to 4 feet is noted, and finally the maximum rise of water in 12 hours from this 4 feet depth is noted. The water-level after 20 hours is also noted. These results are tabulated in the standard form of recupera-

tion test which is given below. The average recuperation of a well is not based on the excavated area of the well but on the inner area of the lining (*i.e.*, either Hexagon or Pentagon or any other forms adopted) for completion. The population being known, the required quantity is calculated on 30 or 20 gallons basis according to the period of the year in which the test is made. The yield of the well is calculated by the total amount of water collected in the well for 12 hours above the 3 feet depth, plus twelve times the sum of the average recuperation between 3 and 4 feet and water-level in 12 hours. This can be expressed in a formulæ as follows :

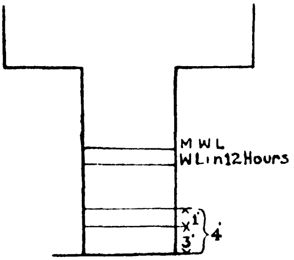


Fig. 23.
Method of taking Recuperation.

Let X gallons be the amount of water required for the village per day ; Y the total amount of water collected in the well in 12 hours above 3 feet depth ; A and B the average recuperation per hour between 4 feet and water-level in 12 hours ;

Sinking may be stopped when :

X is equal to or less than : Y+ 12 (A+B). In practice, however, the well is carried down at least 10 feet below permanent water-table which can be roughly found out by an examination of perennial wells nearby. It is also seen that the minimum depth of water in a well during September to January is 15 feet and during other months 10 feet.

[*Statement.*

W.S.D. Form No. 14.

H.E.H. THE NIZAM'S WELL SINKING DEPARTMENT.

RECUPERATION TEST FORM

Results of recuperation test taken by................
..................Dated..........................,...

1. Name of village ......
2. Block No............
3. Name of well ....
4. Size of well ....
5. Population............
6. Name of contractor ...
7. Date of marking-out the well.. ....
8. Total period taken for sinking the well .....
9. Average depth of sinking per day ....
10. Nature of soil at the bottom of the well ..
    Soft
    Hard
11. Depth of well :
12. Depth at which water was met :
13. Depth at which 2′ overnight recuperation was observed :
14. Depth of water (Overnight).
15. Maximum depth of water :
16. Springs exist towards :
17. Depth of deepest well in the village :
18. When did the deepest well dry last :
19. Number of pumps or mhots employed for bailing water :

Rise of water		Time taken to rise	Inner area of polygon	Recuperated quantity in gallons	Average recuperation in Gallons	Whether water is sweet, drinkable or saline	Remarks
From	To						
0′	3′	..	..	..	.	..	..
3′	4′	..	..	(e)	(a)	..	..
4′	..	..	..	(d)	(b)	..	..
Overnight							

Quantity of water between 3′ and 4′ and between 4 feet and overnight water-level $=c+d=Y$.

Quantity required for the population at.............. gallons per head per day.

..................X.......................gallons.

Yield of well in 12 hours after once the well is full $=X=Y+12\ (A+B)$..............................yield is ' greater/less than the required quantity.

No............................Date.................

Submitted to the Subdivisional Officer.............. for disposal with remarks that.........................

Sectional Officer.

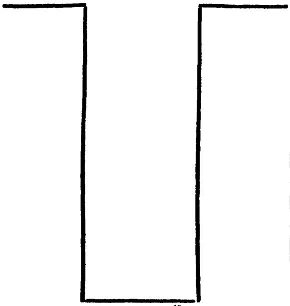
No.........................Date.................

Forwarded to the Special Officer, Well Sinking Department.......................for orders, with remarks that
....
....

Subdivisional Officer.

Instructions on the back of the recuperation test form.

Some of the strata usually encountered under various geological formations are given below		Some important instructions for conducting the recuperation test and recording the results
Gneisses	*Deccan traps*	*To conduct the test*
B.C. soil .. Red soil Chowka & sudda.	B.C. soil .. Exfoliating boulders.	First empty the well completely by dewatering and note the time. Watch the time taken for water to rise to 3′ and from 3′ to 4′ from bottom of well.
Mooram ..	Disintegrated rock.	Note finally the depth of water collected in the well in 12 hours after emptying.
Disintegrated rock Jointed rock .. Massive rock with joints.	Boulders (similar to that in nala bed).	Collect other necessary information for recording the results of the test.
Sedimentary Rocks.	Lithomarge (soft or hard).	*Note.*—The portion of sump of 9 inches depth excavated at the bottom of the well should not be taken into calculation.
B.C. soil ..	Aquiferous rocks red or blue, soft or hard	*Recording the results.*
Shales with concretions.		Fill up the details in the recuperation, test form overleaf and in the sketch alongside.
Shales without concretions.	Trap with gas cavities	*Item* 5.—While giving the population take only so much of the population for which the well has to serve.
Limestones with concretions. Limestones without concretions. Lithomarge Sandstones Conglomerates.	Trap rock mixed with calcites Trap rocks with horizontal joints and fissures Trap rock without any appreciable joints.	*Item* 8.—The period of suspension of work should not be deducted from the total period taken for sinking the well. While calculating the recuperated quantity take the inner area of the completed well irrespective of the excavated area of 4′.

Some of the strata usually encountered under various geological formations are given below	Some important instructions for conducting the recuperation test and recording the results
Laterites. B.C. Soil Soft Laterite Hard Laterite	4′ Pentagonal = 27.53 sq. ft. 4′ hexagonal = 41.57 sq. ft. 7′ pentagonal = 84.30 sq. ft. 7′ hexagonal = 127.30 sq. ft.
Mention in the sketch below the nature and depth of strata encountered in the well under test.	Calculate the required quantity of water taking a consumption of 30 gallons per head per day during September to January (Aban to Isfandar) and 20 gallons during other months.
G.L. Height above M.S.L.  Sump	*Conditions for starting lining.* 1. Yield should be more than the required quantity. 2. The overnight recuperation should not be less than 15 feet for population over 100 and 10 feet for population less than 100.
Subdivisional Officer. .. .. .. Sectional Officer. .. .. .. Remarks by the Head Draughtsman.	3. Excavation should be carried down to not less than 10 ft. below permanent water-table. If any of these conditions are not fulfilled mention reasons for starting lining.

Signature.

No............ Date............

Final orders of the Special Officer.

Besides the above, the following points are also to be furnished.

1. Overnight recuperation just before rains set in (state month).

2. Depth of well when the above overnight recuperation was noted.

3. The approximate difference in ground-level between that of the well under test, and of the deepest well in the village, (so that it may be known whether the well under sinking has gone below the bed of the deepest well).

4. The rate of recuperation in the first foot at the bottom of the well (in cases of wells where heavy recuperation is encountered).

Lining of Wells.

Till the end of 1938 only mass cement concrete without reinforcement was employed for the lining of wells, and it has been found to have satisfactorily withstood the test and strains. But it was found advisable to adopt reinforcement in the cement concrete lining wherever necessary and overlooking the slight increase in cost caused thereby, considering the enormous amount of money invested by Government under this scheme, with a view to lengthening the life and stability of the lining so that the well may prove of utility for long years. Reinforcement was therefore introduced in the linings from 1938 A.D. onwards. For the sake of convenience the same percentage of reinforcement is given for every 10 feet depth of lining calculated on Rankines Formulæ for earth pressure. The mesh or as it is generally called '*Panel Reinforcement*' is introduced in every curb of the lining where sinking is done in loose strata that cannot stand vertical position and consequently exerts pressure on the lining.

The thickness of lining for 4 feet pentagonal wells that was 4.8 inches till 1348 F. was increased to 6 inches in view of scanty supervision and unskilled labour employed, particularly when wells have to be constructed in remote places in the interior. Similarly the proportion of concrete which was 1 : 4 : 8 was also increased to 1 : 3 : 6. (For other details about reinforcement please see page 228).

Before lining is started the bottom of the well or ledge is levelled accurately as any slight departure from the verticality would set up strains which may result in the cement

concrete lining cracking. As this initial work forms one of the most important primary considerations, it has been insisted that the sectional officers should personally supervise the laying of the first curb. The following specifications of cement concrete works should be particularly noted.

1. That the aggregate is always graded, ranging from $\frac{1}{8}$ inch to $\frac{3}{4}$ inch. The idea of using graded metal is to fill up the voids of the bigger metal, the smaller void being filled with sand, and the voids therein being ultimately filled with cement.

Mixing & placing

2. Not more than 5 cubic feet of the metal with $2\frac{1}{2}$ cubic feet of sand and the required quantity of cement for the particular proportion of cement concrete are mixed at a time.

Mixing is done on a watertight platform preferably on a portable steel mixing trough which can be carried from place to place. This has the added advantage of preventing any extraneous material from getting into the mixture or allowing the material being lost.

Mixing

The measured quantity of sand is spread out evenly on the platform and on this the requisite amount of cement is dumped and is evenly spread. The sand and cement are then turned over and over thoroughly, with square pointed shovels, until the mixture forms into a mass of uniform colour free from streaks of brown or grey. The presence of such streaks indicates the incomplete nature of the mixture. This mixture is then spread out evenly on the coarse aggregate placed on the platform. These materials are again turned dry by means of shovels until the aggregate is uniformly distributed throughout the mass. This is then turned at least three times before the mixture is finally ready for further process.

The measured quantity of water is then added to this mixture slowly through a rose of the watercan, while the materials are mixed well with shovels, until the requisite smoothness and workability is obtained. Before the mixture is ready for use, the moulds are placed in position in the well bottom or on the ledge from which lining has to be done.

Placing of moulds in position.

Before the moulds are put in position their inner sides should be cleaned and smeared with oil or cow-dung water. The idea of giving such a wash before each operation is to ensure a clean surface to the concrete after the moulds are removed, as otherwise,

To face p. 220.

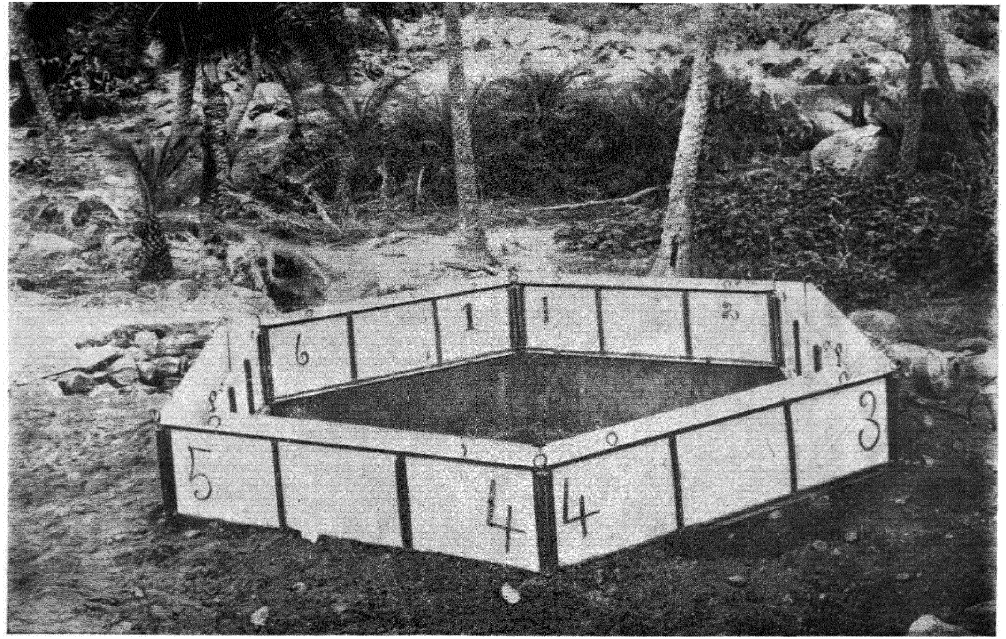


PHOTO PLATE NO. 11—*An hexagonal mould in position for laying the Cement Concrete lining.*

during the removal of these cement may stick to the sides of the moulds and come off with them leaving uneven faces to the lining besides involving unnecessary expenditure for cleaning the moulds afterwards. If even after these precautions are taken the surface of the concrete is not smooth and even, the honeycomb surface should be given a pure cement wash and finished off with a trovel.

The ready mixture is then laid in layers of uniform depth, usually not exceeding 6 inches, into these moulds. Dumping the mixture from a height is avoided as this may separate the metal from finer aggregates. As this process of laying goes on, constant rodding of the concrete is done, by at least three people set up for the work. Side by side with this, the mould plates are gently tapped on the sides by wooden mallets, so that the concrete may form into one solid mass of high density. It is of prime importance to note that the initial set in the cement concrete starts 20 minutes after the mixing ; therefore laying and tamping should be completed within the above time. If the cement concrete is not properly tamped with rods, and if the sides of moulds are not tapped with wooden mallets at the time the concrete is laid, it will result in voids within the concrete to the great detriment of the structure as a whole. This is also attended to by the sectional officers supervising the work, and who are particularly requested to mention this point in their inspection reports.

The moulds are removed after 24 hours, cleaned as before, and, after smearing the faces with oil or cow-dung water again are refixed over the first curb already laid and the second curb laid in the same way as above. The process is thus continued until the required height is reached.

While the curbs are laid, care should be taken to see that no part of the mixture flows through the joints of the moulds as, much of the cement mixed with water will thus be lost thereby reducing the proportion of cement. Under such circumstances the leaks should be stopped by plugging with cloth, or piece of gunny bag or clay whichever best serves the purpose.

The junction of each curb with the other is pointed with cement mortar of 1 : 3 proportion on the inside of the well.

Curing.

This is another important feature in the construction of cement concrete. The mass of concrete should not be allowed to dry as this will

merely dry out the concrete, making the structure useless. The cement concrete lining being vertical, is cured by hanging moist empty cement bags over the entire depth above water level in the well and keeping them in this condition for 4 weeks.

Proportion of water.

There is no hard and fast rule regarding the proportion of water in concrete. It is roughly estimated that 6 gallons of water per bag of cement used for 1 : 2 : 4 proportion, 8 gallons for 1 : 3 : 6 proportion and 10 gallons for 1 : 4 : 8 proportion is found to be quite sufficient.

There are two main factors, which water performs in cement mortar. (1) Just to supply that much of water to bring about the chemical reaction in it and (2) to serve as a lubricant for the cement particles to move freely in filling voids in sand and stone aggregates. Both these changes require a certain fixed amount of water. Any departure from this required addition of water to the concrete, would impair the strength of the material as the physical and chemical changes are either under or overbalanced. The requisite quantity of water to give maximum strength in mortar depends on the kind of (1) cement (2) sand, and (3) weather conditions. As no correct estimates of the quantity of water can be arrived at, there are certain guiding principles which can be followed with advantage.

(1) One part of water to three or four parts of the solid (*i.e.*, cement and sand).

(2) 22 per cent. of water, of cement and sand by volume.

As per above principles, the quantity of water required for 100 cubic feet of cement concrete, works out as follows :

Proportion of concrete	Quantity of water as per		Average
	Rule (1)	Rule (2)	
	Gallons	Gallons	Gallons
1 : 2 : 4	125	94.5	109 75
1 : 3 : 6	114	86.25	100.12
1 : 4 : 8	110	83.60	96.80

This works out to the proportion of water in gallons, given in the opening paragraph of the subject. These quantities are varying according to the size and fineness of the aggregates used and their wetness.

Quality of water.

Regarding the quality of water, it has been found that saline or brackish waters are unsuited for concrete mixtures, as setting of the material is highly interfered with. Hence such waters are not used; any normal potable water would be found good for cement concrete.

Cement concrete lining from ledges.

In the case of wells where ledges are left the cement concrete lining is started from the ledges in the same way already described. The moulds are arranged on the ledges and filling of cement concrete is done and finished as detailed in the foregoing paragraphs. If the ledges are above water level the process of lining can be finished earlier without de-watering the well.

Under such cases the ledges may project in such a manner that the pots let into the well may strike the sides; in order to overcome this trouble, grooving of 3 feet width is done from the ledge downwards. Grooves are also cut below portions for the provision of the maximum number of pulleys, irrespective of the number of pulleys actually installed at the time of completion of the wells, which will facilitate in fixing the maximum number of pulleys when such need arises.

Ledges in hard rock are invariably left in the case of the 7 feet hexagonal and 7 feet pentagonal wells, but if on account of the unstability of the ledges for founding the lining or for other technical reasons, it is not possible to leave ledges and further excavations have to be made in hard rock the matter should be referred to the Special Officer.

Cement concrete linings which serve as mhot foundations in soils exceeding 20 feet deep.

In cases where the depth of soil (soft) exceeds 20 feet, and the cement concrete lining can serve as walls for mhot also the following methods are adopted.

(1) The well is excavated by widening at the top until hard soil is met with, and the debris hauled to the surface. As an alternative lining is constructed by the Reverse Method.

(2) When hard soil is met with, 7 feet pentagonal cement concrete lining is constructed right up to the groundlevel.

(3) The filling behind cement concrete lining is done with boulders and sand whichever is cheaper to a width of 6 feet all round and the rest with available soil (please see further modifications of filling behind cement concrete lining page 234).

(4) The well is further excavated below ledge in a diameter of 9 feet.

(5) *i.* No cement concrete lining is constructed below the ledge if the soil below it is hard enough to withstand the weathering action.

ii. The ledge which will be about 5 inches is covered by laying a cement concrete slab of 6 inches thickness in 1 : 3 : 6 proportion as shown in the sketch. This is to prevent the weathering action of the top of the ledge by constant water action.

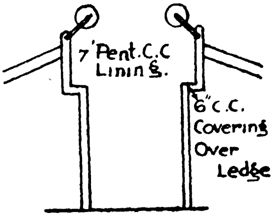


Fig. 24

iii. The big type of bent armed pulleys is fixed to the parapet of 7 feet pentagon.

iv. Masonry platforms are not constructed as, due to great depths of B. C. soil, they are liable to sink down however much watering and tamping are done. In the first instance sand and shingle to a thickness of one foot is laid to a width of 5 feet. This applies to 4 feet pentagonal wells also where huge widening and subsequent filling are done.

(6) *i.* On the other hand if the soil below the ledge is of soft nature, 4 feet pentagonal cement concrete lining is constructed from the bottom of the well to a height 6 inches above the ledge. In this case the top portion of the 4 feet pentagonal cement concrete lining is reinforced with the required type of panel reinforcement to withstand the lateral pressure of the weight of the 7 feet pentagonal cement concrete lining on the ledge.

ii. The space between the top 6 inches of the 4 feet pentagonal cement concrete lining at the bottom of the 7 feet pentagonal cement concrete lining is filled up with cement concrete of 1 : 3 : 6 proportion so that the top soil of the ledge may not get deteriorated.

iii. The pulleys fixed on the 7 feet pentagonal parapet will not serve the purpose now, as the pots that are lowered will strike the sides of the 4 feet pentagonal cement concrete lining. To overcome this difficulty reinforced cement concrete beams are laid across the well, over which a 6-inches thick reinforced cement concrete slab is laid. These slabs are pre-cast by the side of the well, and after curing, pushed into position thus dispensing with any centering arrangements as shown in the design in Appendix.

iv. 6 inches thick reinforced cement concrete parapet is constructed over these beams.

v. No platform is constructed in this case as the slab itself would serve the purpose of the platform which is however provided with retaining wall at the sides.

Contractors are not allowed the use of their own cement. This is supplied to them on sale by the department for use on the construction of mhot walls, etc. In order to exercise proper check the sectional officers have to record the measurements of such work done and calculate the cement required and to see that the contractor has purchased that much quantity of cement and paid for. This arrangement eliminates the misuse of Government cement by the contractors.

The subdivisional officers during their inspection are asked to verify the details of such masonry constructed and the quantity of cement used and to make a note in their inspection reports.

Wherever rates for concrete and masonry works are allowed with government cement, carting of cement from the nearest godown is paid at the rate of Re. 0-3-0 per mile per cart load of 10 cwts.

The depth of sump or the depth of the boulder filling at the bed of the well to make a proper foundation for laying cement concrete lining, is not included in the depth of the well inscribed in the number plate. Payment for excavation and boulder packing is however made.

Proportion of Cement Concrete.

The various proportions of cement concrete to be used on different items of work are as follows :

All curbs of C. C. Lining excluding parapet 1 : 3 : 6 (each curb is 2 feet high).

Parapet or topmost curb : 1 : 2 :4.

Cement concrete rectangular cattle-trough 1 : 3 : 6.

Plastering in cement mortar 1 : 3.

Weep-holes.

While casting the cement concrete lining, weep-holes of three to four inches diameter are left in the centre of every side of the pentagon or hexagon between 2 feet height of curbs. These weep-holes are left to a height of about 6 to 8 feet from bed so that the spring water can have easy access into the well.

Iron steps.

Iron steps are fixed one each at the junction of every two curbs at one of the corners of the lining up to about 4 to 5 feet below the top of the parapet. The topmost step is kept at the above depth in order to prevent people from easily getting into the well and spoiling the water. So for a 40 feet cement concrete lining the number of steps used will be $\frac{40-4}{2}=18$, and for a lining of 31 feet the number of steps will be $\frac{31-5}{2}=13$. The method of fixing the iron steps in the cement concrete lining is shown in the sketch below :

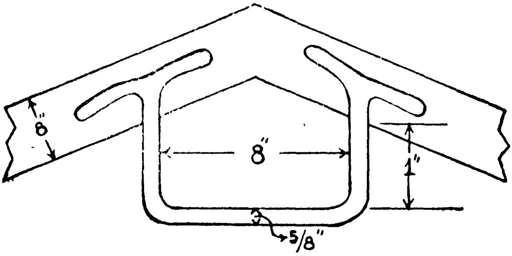


Fig. 25.—Method of fixing Iron Steps.

As 100 Cu. Ft of coarse aggregate
50 do Sand and
25 do Cement give a total of nearly 110 cubic feet of cement concrete, the table below is worked out for different quantities of aggregates sand and cement to give 100 cubic feet of concrete.

Proportion	Cement in bags	Sand in C. ft.	Coarse aggregate in C. ft.
1 : 2 : 4	18	45	90
1 : 3 :6	12	45	90
1 : 4 : 8	9	45	90

A statement of cubical contents and quantities of cement required for various items of the well is shown below :

Statement of dimensions (cubical contents) and quantities of cement required for the various items of a 4 feet sided cement concrete pentagonal well.

Particulars	No.	Dimensions			Quantity	Quantity of cement required in bags			Remarks
		Length	Breadth	Height		For masonry	For plastering ½" thick 1 : 3 proportion	Total	
Inner side of C.C. lining ..	..	4′ 0″	..	..	..	..	..	..	..
Outer side of C.C. lining ..	..	4′ 8⅔″	..	..	..	..	..	..	..
Thickness do ..	..	..	0′ 6″	..	..	..	..	..	..
Radius of inscribed circle ..	..	2′ 9″	..	..	..	..	..	..	..
Radius of circumscribed circle	..	4′ 0″	..	..	..	..	..	..	..
C.C. lining per foot height ..	5	(4′+4′ 8⅔″)/2	0′ 6″	1′ 0″	Cu. Ft. 10.90	..	..	..	..
Do 1 : 2 : 4 curb of 2′ high	5	do	0′ 6″	2′ 0″	21.80	4.00	0.50	4.50	..
Do 1 : 3 : 6 do ..	5	do	0′ 6″	2′ 0″	21.80	2.50	0.50	3.00	..
Deduction for each gap in parapet for landing the pots	2	0′ 11⅛″	0′ 6″	1′ 0″	0.93	0.25	..	0.25	..
Plastering parapet ..	..	..	..	..	..	..	0.50	0.50	..
Full platform	5	(4′ 8⅔″+10′ 10½″)/2	4′ 3″	0′ 3″	124.29	3.25	..	3 25	..
String course for full platform	5	(9′ 1″+9′ 9½″)/2	..	..	47.19	0.25	..	0.25	..
Treble pulley platform ..	2	(4′ 8⅔″+10′ 10½″)/2	4′ 3″	0′ 9″	90.07	2.375	..	2.375	..

	2	(5′ 6″+7′ 2″)/2	4′ 3″	0′ 9″	..	..	..	..	..
String course for treble pulley platform	2	(9′ 1″+9′ 9½″)/2 + (5′ 4″+6′ 1⅓″)/2 + (3′ 2″+3′ 8″)/2	..	..	36.15	0.125	..	0.125	..
Double pulley platform ..	1	(4′ 8⅓″+10′ 10½″)/2	4′ 3″	0′ 9″	65.22	1.75	..	1.750	..
	2	(5′ 6″+7′ 2″)/2	4′ 3″	0′ 9″	..	..	..	..	..
Double pulley platform string course.	2	(9′ 1″+9′ 9½″)/2 + (5′ 4″+6′ 1⅓″)/2 + (3′ 2″+3′ 8″)/2	..	..	27.71	0.125	..	0.125	..
Single pulley platform ..	2	5′ 7⅓″	4′ 3″	0′ 9″	35.95	1.00	..	1.00	..
Single pulley string course	2	(3′ 8½″+4′ 4″)/2	..	..	16.85	0.10	..	0.10	..
	2	(4′ 1″+4′ 8⅔″)/2	..	..	0.69	..	..	..	..
U.C.R.S. masonry drain per R.ft.	1	1′	1′	¾′	81.00	..	..	..	..
Minus	1	1′	¼′	¼′					
Dry rubble pitching 1′ thick	1	10′ 6″	9′	1′	38.40	..	..	..	..
Minus	1	4′ 6″	3′	1′					
Outer area of pentagon ..	5	4′ 8⅓″/2	3′ 3″	..	27 50	..	..	..	..
Inner do ..	5	4′ 0″	2′ 9″						
Rectangular cattle-trough ..	1	13′ 0″	0′ 6″	0′ 9″					
1 : 3 : 6	1	4′ 6″	3′ 0″	0′ 9″	15.00	1.75	0.25	2.00	..

To avoid the use of allocation of cement by fraction of bags on various items of cement concrete lining and masonry works, the following quantities of cement are used :

Serial No.	Items	Actual quantity as per calculation	Quantity to be used in round number of bags
1	Curb of 2′ height in 1 : 2 : 4 proportion (parapet) including rendering and pointing between curbs and irrespective of numbers of landing pot gaps (no deductions for landing pot gaps are made in the allocation) ..	3 92 Bags	4.00 Bags
2	Curb of 2′ height in 1 : 3 : 6 proportion including rendering and pointing between curbs	2.62	3.00
3	Full platform including string course masonry wall	2 93	3.00
4	Treble pulley platform including string course masonry	2.13	2.00
5	Double do do ..	1.55	2.00
6	Single pulley platform including string course masonry ..	0.86	1.00
7	Cattle trough 1 : 3 : 6 proportion ..	1.80	2.00

For construction of stone masonry drain of about 10 feet length (the exact length depending upon the nature and slope of the ground) the quality of cement required is only 0.15 bag. Savings to the extent of this quantity is made from the cement on platform. No extra allocation is therefore given separately for the drain.

Reinforcement in cement concrete lining.—

The cement concrete lining of wells is reinforced by means of M. S. Bars fabricated into meshes as shown in Appendix. This reinforcement is used in portions where :—

1. The soil at the sides of the well cannot stand vertical.

2. The horizontal width of filling from the outer face of cement concrete lining is more than 3 feet.

To be on the safe side, the extra 2 feet of lining towards the bottom is reinforced over and above the required depth, *e.g.*, if X feet of lining requires reinforcement it is made X +2 feet.

In addition the parapet and the two lower curbs are reinforced. Each mesh is made for one panel (side) of a curb and is called by the name of '*Panel Reinforcement.*' The types change for every 10 feet depth of lining below ground-level.

Method of Reinforcement.

When the moulds are ready in position, the panel reinforcement is placed vertically into the sides of the mould almost touching the inner plate. The extra length of 6 inches of the fabric is bent on either side by 3 inches outwards and the extra height of 3 inches is left above the curb, so as to get into the next curb that may be cast above. When the concrete is being laid in the mould, the reinforcement is shifted automatically by about ½ to ¾ inch into the heart of the concrete due to the rodding and tamping of the concrete. Reinforcement is so regulated that nothing less than ½ an inch or more than one inch of it is covered by the concrete on the inner side.

Reinforcement in the Parapet.

This is provided to the exterior of the lining instead of the interior. The reinforcement to be provided in the parapet should be cut in the portion where a gap is made in the parapet for landing the pots. The cut portion of the reinforcemnt is placed in front of the pulley legs towards the interior of the lining as shown in the sketch below.

If a curb of cement concrete lining to be laid is of a height less than 2 feet the panel reinforcement should be so cut that, the vertical reinforcement is embedded in the upper curb to the extent of 3 inches. The ends of horizontal bars should be bent towards the heart of the concrete as shown in the sketch.

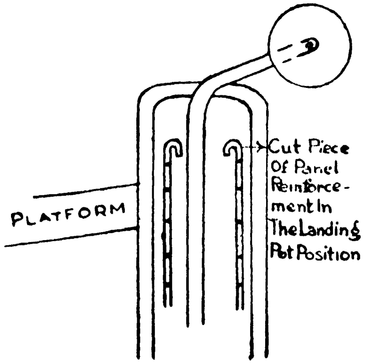


Fig. 26.

Type of Reinforcements to be used at different depths.

TYPE	
4-P / 0-10	is used between 0 and 10 feet below and above ground-level.
4-P / 10-20	to be used between 10 and 20 feet below ground-level.
4-P / 20-30	to be used between 20 and 30 feet below ground-level.
4-P / 30-40	to be used between 30 and 40 feet below ground-level.
4-P / 40-50	to be used between 40 and 50 feet below ground-level.

The sketches of these types are enclosed in Appendix :

Due to high cost of M. S. Bars and sometimes the non-availability of certain sections, some changes had to be made during the last half of 1941.

Carrying Capacity of Carts due to unwieldy nature of Panel is given below :—

Panel reinforcement for 4 feet pentagonal.

0′ -10′	Type	.. 10 bundles of 25 each in a cart.
11′ -20′	do	.. do
21′ -30′	do	.. do
31′ -40′	do	.. Loose bars at 10 Cwts. per cart.
41′ -50′	do	.. 9 bundles of 10 each in a cart.
51′ -60′	do	.. 8 do
61′ -70′	do	.. 10 do
Iron Steps :		.. ½ a ton per cart.

Panel reinforcement for 7 feet pentagonal of all types : Loose bars at 10 Cwts. per cart.

De-watering while lining.

Extra de-watering charges are paid only on the following items. (1) Recuperation test (one day), and (2) every 2 feet of cement concrete lining which requires bailing of water (one day).

Water Bailing charges during Cement Concrete lining below Water-level.

The bailing charges are calculated in the following manner.

1. If the overnight recuperation is 12 feet bailing charges are paid for $\frac{12}{2} = 6$ days.

2. The column of water above the level of overnight recuperation is divided by 4 and the overnight recuperation, as pointed out above, by 2, and the bailing charges paid on the figure arrived at, *e.g.*, if the maximum water depth is 40 feet, bailing charges are paid $\frac{40-12}{4} = \frac{28}{4} = 7$ days ; therefore the total bailing charges that can be paid for cement concrete lining works out to=(1)+(2)=6+7=13 days.

Pumping charges with 2 power-pumps are allowed only when the recuperation of water is more than 4,000 gallons per hour.

Widening and Silt Removal.

The accumulation of silt is usually due to the following causes. (1) The muck stacked near the well, is usually washed into the well by rains, as shown in the sketch by the side, A representing the muck staked.

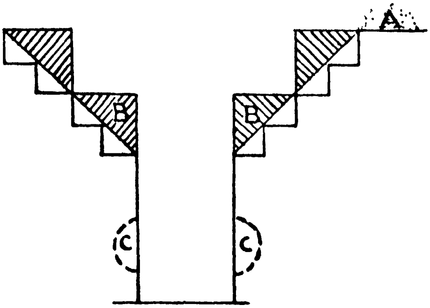


Fig. 27.

(2) The slipping of the sides due to soft nature of the soil on the top portion of the well (B of sketch).

(3) The caving of the sides of the well (C of sketch).

In cases of (2) and (3) the silt removal is paid, whereas in the case of (1) no payment is made to the contractor.

The muck removed from the well is stacked at a distance of not less than 40 feet from the edge of the well. Payment is not made in cases of all three items mentioned above if the accumulation of silt is due to unauthorised suspension of work. In case of item (2) mentioned above the correct procedure of payment adopted is as follows :

A well sunk to 75 feet depth for 4 feet pentagonal lining is afterwards widened as shown in the sketch by the side to a depth of 15 feet, on account of which silt accumulates at the bottom of the well to say 10 feet depth. In this case payment for widening and silt removal is paid in the following manner.

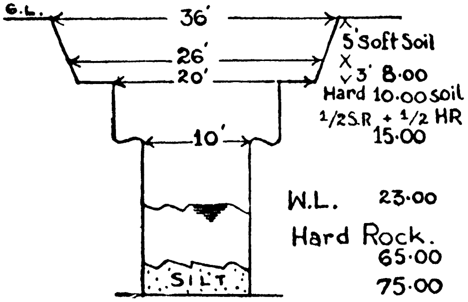


Fig. 28.

1. *Widening in B. C. Soil* 0 *to* 5 *feet.*

$$\left(\frac{3.14}{4}\times\frac{36^2+26^2}{2}-94.98\right)5'=3{,}395.15 \text{ C.ft.}$$

(The standard diameter of excavation in soft soil is 11 feet and the area is 94.98 square feet).

Deduct silt fallen in the well (in proportion to depth) $5/15 \times 78.5 \times 10 = 261.40$ C.ft.

Balance : 3,133·75 at Rs. 7-8-0 per thousand cubic feet=Rs. 23-8-0 (78.5 being the area of 10 feet diameter excavation and Rs. 7-8-0 being the P.W.D. rate for well sinking between 0 to 5 feet).

Widening in B.C. Soil from 5 to 8 Feet.

$$\left(\frac{3.14}{4} \times \frac{26^2+20^2}{2} - 94.98\right) 3 = 982.05 \text{ C.ft.}$$

Deduct silt fallen in the well.

$3/15 \times 78.5 \times 10 \qquad = 157.00$ C.ft.

Balance at Rs. 8-8-0 per thousand cubic feet=7-0-2 (8-8-0 being the P.WD. rate for well sinking between 5 to 10 feet).

Widening in hard mooram : From 8 to 10 feet.

$$\left(\frac{3.14}{4} \times 20^2 - 78.5\right) 2 \qquad = 471.00 \text{ C.ft.}$$

Deduct silt fallen in the well :

$\frac{2}{15} \times 78.5 + 10 \qquad = 157.00$ C.ft.

Balance :....................=314.00 at Rs. 13-8-0 per thousand cubic feet=4-3-10. Widening in half rocky mooram, with pick and crowbar and half rock blasting (Trap)

$$10' - 15' = \left(\frac{3.14}{2} \times 20^2 - 78.5\right) 2 = 1177.550 \text{ C.ft.}$$

Deduct silt fallen in the well :

$\frac{5}{15} \times 78.5 \times 10 \qquad = 261.41$ C.ft.

Balance : $\qquad = 916.10$ C.ft.

at Rs. $\frac{32\text{-}5\text{-}0 + 108\text{-}10\text{-}0}{2}$ per thousand cubic feet =64-8-9.

Payment is made for excavation of the quantity of soil falling into the well during widening (without allowance for any lift) as shown below :—

Excavation in B.C. Soil= $\frac{8}{15} \times 78.5 \times 10 = 419.00$ at Rs. 7-8-0 per thousand cubic feet=3-2-3.

Excavation in hard mooram= $\frac{2}{15} \times 78.5 \times 10$ at Rs.10-8-0 per thousand cubic feet=104.40= Rs. 1-1-6.

Excavation in $\frac{1}{2}$ rocky mooram with pick and crowbar and $\frac{1}{2}$ rock requiring blasting $=\frac{5}{15}\times 78.5\times 10=261.4$ at $\frac{26+58}{2}$ per thousand cubic feet $=$ 10-15-5.

Silt removal is then paid for at the usual rate of Rs. 2-0-0 per hundred cubic feet above water-level and Rs. 2-8-0 per hundred cubic feet below water-level for the soils and rocks that have fallen into the well (no extra bailing charges are paid for).

In this connection the following equivalent classifications of Well Sinking Department and the Public Works Depart-are taken into account.

CLASSIFICATION

Well Sinking Department	Equivalent Public Works Department
1. Soft Soil	.. B.C. Soil, Red Soil, Sandy Loam, Loamy Clay, Hard Clay, Chowka, Soft Mooram, Sudda Soil.
2. Hard Soil	.. Hard Mooram, Very Hard Mooram.
3. Soft Rock	.. Disintegrated Rock, Rocky Mooram with pick and crowbar, rock requiring some blasting.
4. Hard Rock	.. Blasting sheet rock with or without face, blasting trap and granite.

After the lining is completed, the well is finally cleaned, by pumping out or bailing out by mhots all the water in the well, washing the sides, etc., and removing any muck that may have collected at the bottom, and then allowing the well to recuperate.

It happens in certain cases that the mhot or pump method of de-watering for final cleaning of the well may not be possible; under such circumstances the Tripod method of bailing water is adopted under supervision of the Mechanical Engineer if the exigencies of the situation so demands.

Filling behind Cement Concrete Lining.

After the cement concrete lining is completed, the space behind the lining is to be filled up; this is done with the avail-

To face p. 236.

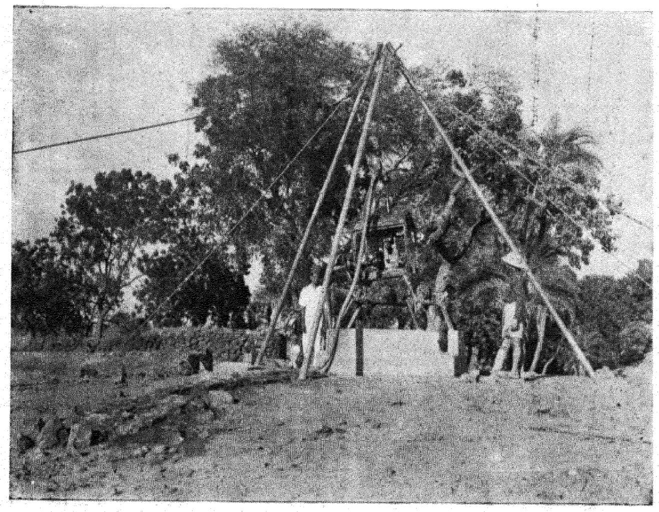


PHOTO PLATE NO. 12.—*The tripod method of hoisting power pump in position for bailing water for final cleaning of the well after completion.*

To face p. 237.

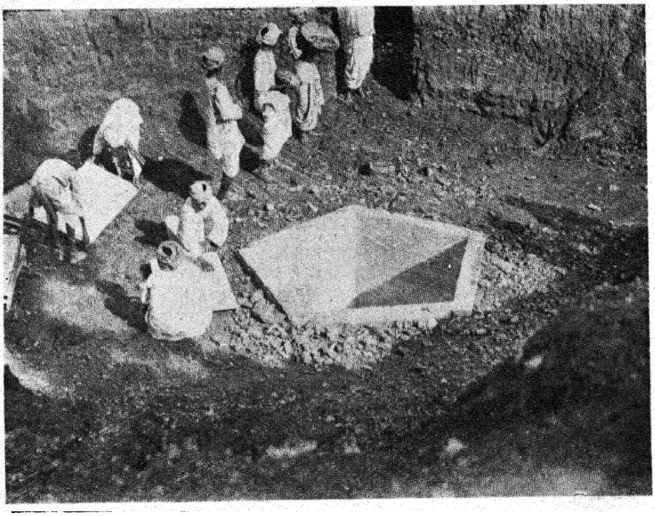


Photo Plate No. 13.—*A well under cement concrete lining. Note the widening done in soft soil. Filling behind lining is done by boulders, but sometimes sand is used if available cheaper.*

able boulders got from either the excavation of the well or from neighbouring places. These boulders are closely packed up to the level of springs or to a height of 10 feet from the bottom, whichever is less. While payment for boulder filling is made, 40 per cent. for voids is deducted. Above the filling of boulders, available mooram is filled up in layers, watered and tamped. This is done to ground-level. The watering and tamping is so conducted as to consolidate the material as much as possible so that no sinking may take place later on which may result in the unstability and cracking of the platform that may be laid on the filling. Tamping is done with 10 lbs. tampers to ensure a stable finish.

In cases of wells situated in shales, boulders which are carted from available places to the spot are filled in to a depth of 30 feet or the maximum water-level whichever is less from the bottom of the well and above this the available soil or shale is used, watered and tamped. Shale fillings are not adopted at lower levels as these will crumble after soakage of rainwater, resulting in blocking the springs entering the well.

Where widening at the top has been done in loose soil, boulder filling is done to the width of platform plus one foot extra, *i.e.*, 5 feet 3 inches all round the lining to build a stable platform over it. This will safeguard against undue thrust on the lining and eliminate settlement of the platform which needs greater stability.

During later half of 1941, it was decided that filling behind lining from bottom to ground-level, should only be done from the boulders got by excavation or obtained by carting from other places, provided the whole work can be done cheaper than filling with sand which may be available in nalas nearby. Boulder filling from bottom to top is therefore now adopted.

In cases where widening is done in loose soil beyond the standard diameter, filling is done with excavated soft or hard rock and the rest of the material is got from other places and filled in, or sand is used, whichever is found cheaper. The width of such filling is increased to 6 feet all round the lining. The filling between ground-level and bottom of platform is done with well-packed boulders.

Surface Work.

The surface work includes the construction of parapet, platform, drain and cattle-trough and fixing of pulleys and number plate into the parapet.

Parapet.

The parapet, which is the top-most curb of the cement concrete lining, is kept 2 feet high above the platform level, the platform itself being 1 to 1½ feet from ground-level, will maintain an efficient drainage of water from it. The outer corners of the parapet wall are not chamfered, but are neatly rounded up. The lining does not require any plastering, but, wherever necessary, patch-work is done to bring it to a proper finish and smoothness to conform to the original concrete. When the parapet is being laid, the concrete is filled 1 inch less from the top of the mould, on the surface of which a layer of water will result by tamping the concrete. On this a dry mixture of cement and sand in the proportion of 1 : 3 is filled up not only to fill the 1 inch gap, but also to stand 1/2 to 1 inch above the mould. This dry mixture will set by the water floating on the surface of the concrete laid and some more water is added if necessary. The top of the parapet is thus finished with a trowel giving nearly a flat top with rounded sides. This gives a homogeneous structure without development of cracks at a later date.

While the parapet is being cast, as many openings as the number of pulleys that are to be fixed are left for landing the pots. These openings are according to dimensions mentioned in the standard designs. In cases of 4 feet hexagonal and pentagonal wells these openings are left at the corners, but whereas in the case of 7 feet hexagonal and pentagonal wells they are left at the sides, as the pulleys are fixed at the corners in the former and at the sides in the latter. The surface of these landings for pots are sloped outside, to drip down the spill water on the platform instead of into the well.

Fixing of stanchions for pulleys.

Before casting the parapet, the stanchion legs for the support of pulleys are to be introduced in the concrete. These legs are 2 feet 6 inches high, up to the bends, and when the lower curb below the parapet is cast, the concrete in the moulds are filled to a height of 1 foot 6 inches, when the stanchion legs are put in position and further concrete to the remaining 6 inches is filled in and tamped. Supports to hold the stanchions in position are given. Then the last curb which forms the parapet is cast with openings for landing of pots as described above. After the concrete sets and other minor works are finished the supports of the stanchions are removed. The stanchion legs are not painted up to the limits of the bends, so that concrete may adhere to its sides and hold them firmly. The ' C ' design or small pulleys, details of which are shown

To face p. 239.

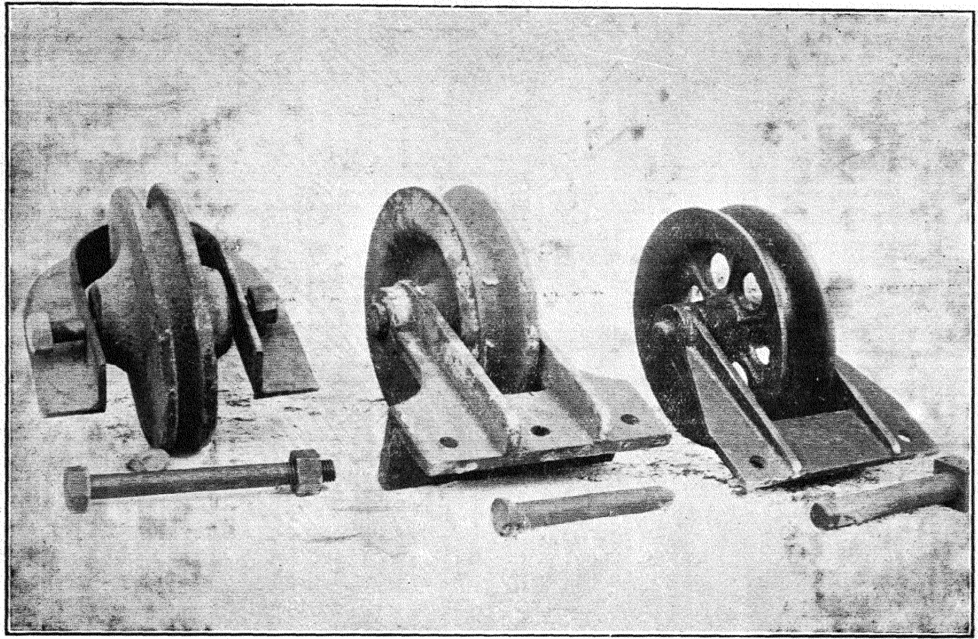


Photo Plate No. 14.—*Types of iron pulleys that were evolved at different stages, in order to get at the best and the most lasting design.*

To face p. 239.

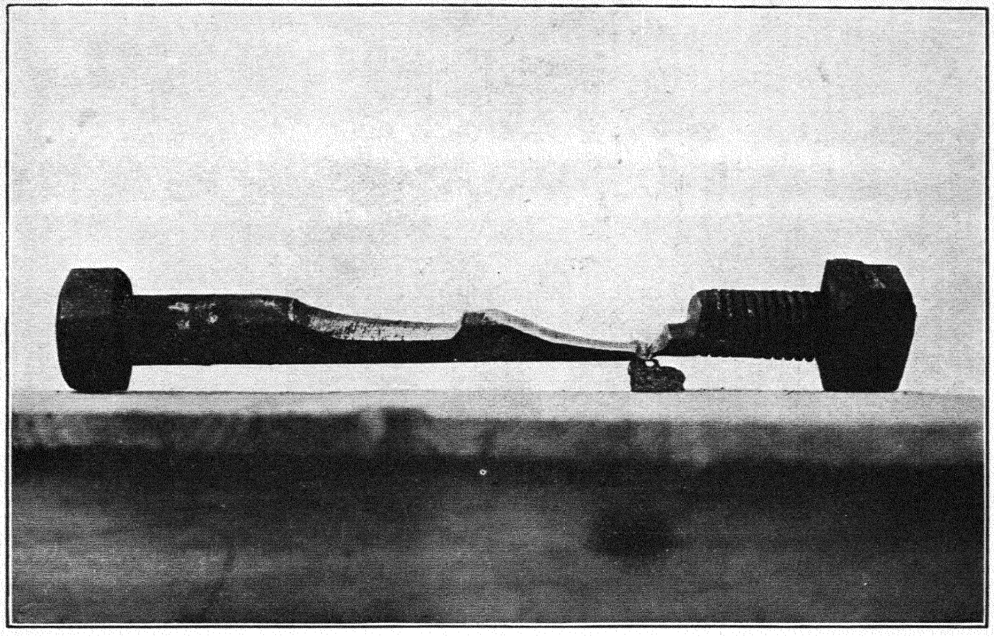


PHOTO PLATE NO. 15.—*The wear and tear on mild steel axles of pulleys. Due to imperfect oiling and rough handling, these are irremediable and non-replaceable by the villagers.*

in Appendix are fixed to 4 feet hexagonal and pentagonal wells, and 'A' design or big pulleys shown in Appendix VI are fixed to 7 feet hexagonal or pentagonal wells.

In order to safeguard against cracks in the cement concrete lining due to vibrations of the pulley legs caused by non-oiling the axles, the reinforcement of pulley legs in addition to the panel reinforcement in the parapet was subsequently adopted during the last half of 1939.

Cast-iron pulleys with mild steel axles are then fitted at the spaces provided.

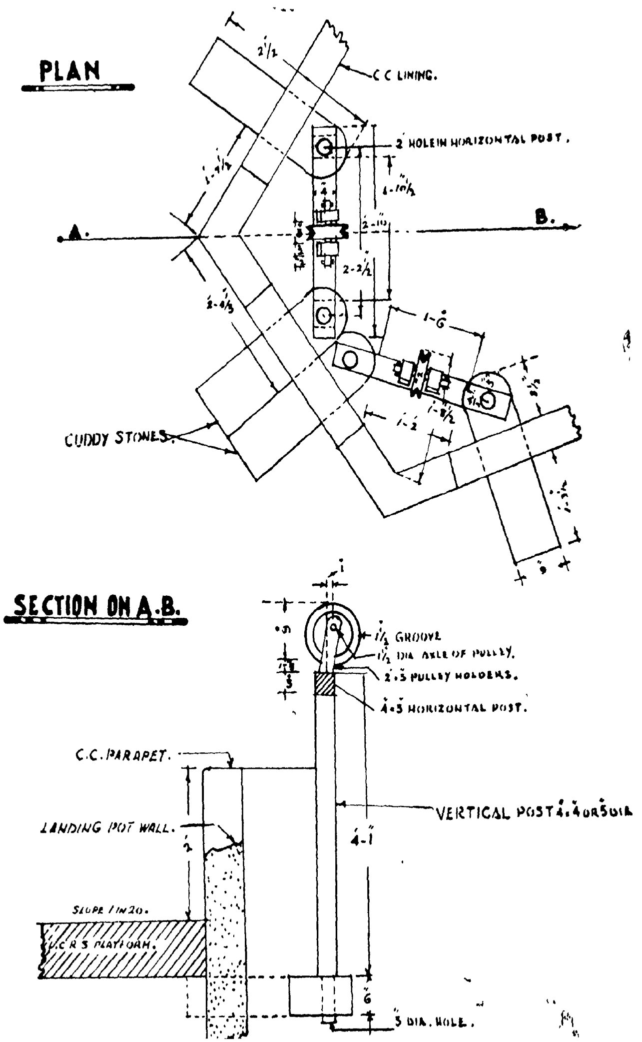
The width of the opening for landing pots which were till the end of 1939 1 foot 7 inches, were reduced to 1 foot 6 inches to give an increased protection for the stanchion legs on sides.

Later developments of stanchions and pulleys.

Due to imperfect oiling, the wear and tear in cast-iron pulleys and M. S. axles were found to be irremediable by the villagers and in order to avoid these drawbacks, it was thought advisable to introduce wooden pulleys and axles which can be replaced easily by the village carpenter. So during the last quarter of 1940, the substitution of jungle wood in place of C.I. pulleys, M. S. axles as well as the legs of the stanchions was adopted. These are fixed on cuddy stones about 3 feet long embedded under the parapet lining and projecting out 9 inches. The design is enclosed herewith. This method of adoption, besides saving the cost in wells also increases the life of the parapet as similar vibrations set up by the iron stanchions, are now almost minimised or altogether made wanting.

DESIGN OF FIXING WOODEN PULLEYS ON WELLS

SCALE:- 6" = 1 FOOT



Platforms.

This forms one of the important items in construction and as already pointed out, the weakest structure requiring greater stability the following precautions are observed before laying them.

I. Filling at the back of lining is stopped at 1 foot 6 inches below ground-level, and the top surface of earth levelled all over uniformly. Then water is allowed to stand on this surface for a period of 2 days. In order to facilitate this work, the delivery pipe of the pump while under final cleaning of the well, may be directed to discharge on this surface. At first the water would drain down the soil, which may also sink with it, when further filling is done with watering and tamping. This process is repeated until the surface sinks no further. Over this, stone filling is done to the required level over which the platform is constructed.

The platform is built in stone masonry to a thickness of about 1 foot and irrespective of the types of the well is 3 feet 9 inches wide from the outer face of the lining to the inner face of the string course retaining wall. The string course retaining wall whose width should be uniform and may vary from 4 inches to 8 inches depending upon the available size of stones, consists of rectangular blocks of stones placed on edges, in such a manner that 5 inches or more of the stone is embedded into the masonry of the platform and the rest 3 to 4 inches forming the height of the retaining wall. The total width of the masonry bed of the platform is 5 feet, the end 9 inches being not visible on the surface due to earth covering. The platforms are built with transverse slopes of 1 in 20 away from the parapet, and with longitudinal slopes of 1 in 50, 1 in 40 and 1 in 30 respectively in different panels sloping towards the drain.

Size of platforms.

The size of platform depends on the number of pulleys that are to be fixed to the well. If only one pulley is fixed, 'single pulley platforms' are constructed as shown on the standard design in Appendix. When two pulleys are provided 'double pulley platforms' are constructed as per standard design shown in Appendix. In all other cases, *i.e.*, when the number of pulleys are more than two, full platforms are built as shown in Appendix.

If any material is remaining from the spoils of the excavation of the well after filling behind the lining it is evenly

spread all round the platform up to the top of the retaining wall. This will ensure the retaining wall from being damaged. A rate of Rs. 5-0-0 per thousand cubic feet will be paid for this work of site clearing and levelling. If spreading of this material is objected to by field owners, when wells are situated in or near their fields due to part of their land getting stone logged, then extra spoils are heaped up with slopes trimmed along the foot path leading to the well.

On working out the comparative costs of constructing platforms (1) rubble stone masonry in cement mortar of 1 : 12 proportion; and (2) three inch cement concrete blocks laid over a layer of cement mortar, it was found out that the costs in the two cases were practically the same. As such, where stones are not available and entail carting from long distances involving the payment of lead, platforms of cement concrete blocks are constructed. In constructing this type of platform, a layer of sand is first spread to the width of the platform, over which cement mortar of 1 inch thick in 1 : 12 proportion is laid. On this the 3 inch thick cement concrete blocks of 1 : 4 : 8 proportion are laid. The blocks may be of any suitable size, precast and placed together, the joints being filled with cement mortar as in the case of stone masonry.

Platforms for wells on nala banks

For wells situated on nala banks, with their ground-level below the maximum water-level of the nala the platform is raised 1 foot above this maximum water-level. When the height of the platform above ground-level exceeds 2 feet, earth-filling is done having a top width of 5 feet with $1\frac{1}{2}''$ to $1''$ slope at the ends. Turfing is

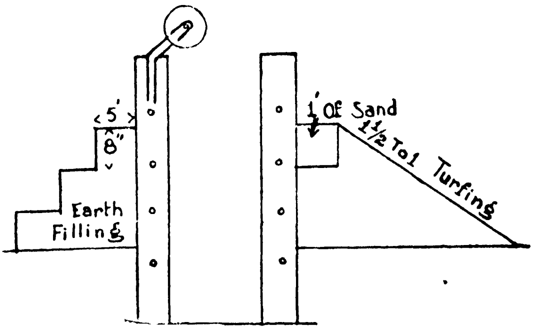


Fig 29.

done on these slopes all round to the level of the platform. These turfs are watered for 3 months. In such cases instead of masonry platforms, 1 foot of sand is laid at the top as

shown in the sketch. If boulders or rocks are available the platforms are made of these, otherwise earth is used. Stone steps 3 feet long with 1 foot tread (width) and 8 inches rise (thick) are provided for people to get up and down the platform.

To calculate quantities of materials required for coursed rubble stone and uncoursed rubble stone masonry.

The proportion of cement mortar that is generally used in this department for stone masonry work is 1 : 12 (1 cement and 12 sand). It is taken that the stones contain about 40 per cent. of voids and in order to fill up all these voids, about 40 cubic feet of cement mortar for every 100 cubic feet of stone for masonry are required. Thus for 1 : 12 proportion of cement mortar, the quantity of cement required=40/12 =3.3 cubic feet or 3.33/1.25 =2.65 bags of cement, 40 cubic feet of sand and 100 cubic feet of stones.

Cattle trough.

The cattle trough is constructed by the side of the platform and as a separate unit so that when it has to be used, the villagers can draw water and pour into it.

Drain.

The drain leading the spill water from the platform is not connected to the cattle trough as then the water that will accumulate into it will be too polluted for animal consumption. Hence the drain is constructed to a sufficient length in stone masonry depending on the slope of the ground and other requirements.

Number Plates.

In the beginning stages the fixing of number plates was not thought of, but later on it was found advisable to fix number plates on wells new or remodelled. After undergoing through a process of evolution the final design now adopted is as shown in the margin with letter N before the serial number of the well in the taluq standing for new wells and R for old wells remodelled. The depression at the bottom is provided for marking the depth of well from top of parapet by means of dies owned by the contractors. Finally the figures are tarred to make them bold. The cost of the above is included in the cost of fixing the number plate.

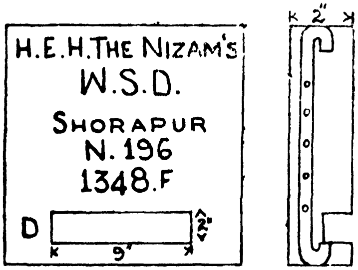


FIG. 29

In order to avoid confusion and sometimes repetition of serial numbers by mistake the subdivisional officers besides checking them on wells maintain regular registers. As a further check the details of the number plates are also noted in the measurement books along with the final measurements recorded for the work.

With regard to serial numbers of lost or broken tablets the head store-keeper is kept informed by the subdivisional officer so that fresh tablets with those serial numbers may be manufactured. Lost tablets if found out afterwards, are returned to the Stores.

To face p. 244.

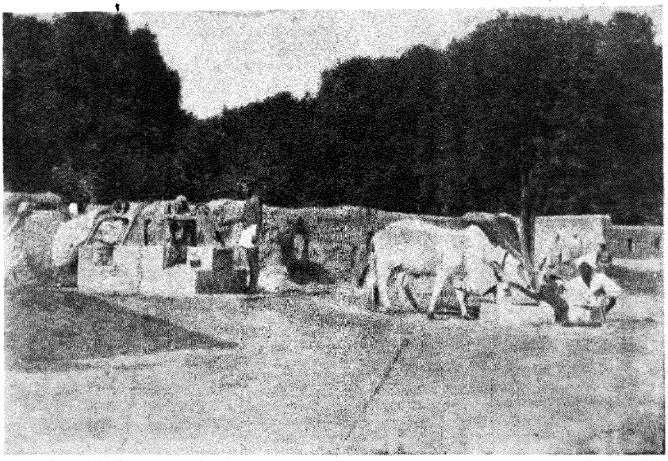
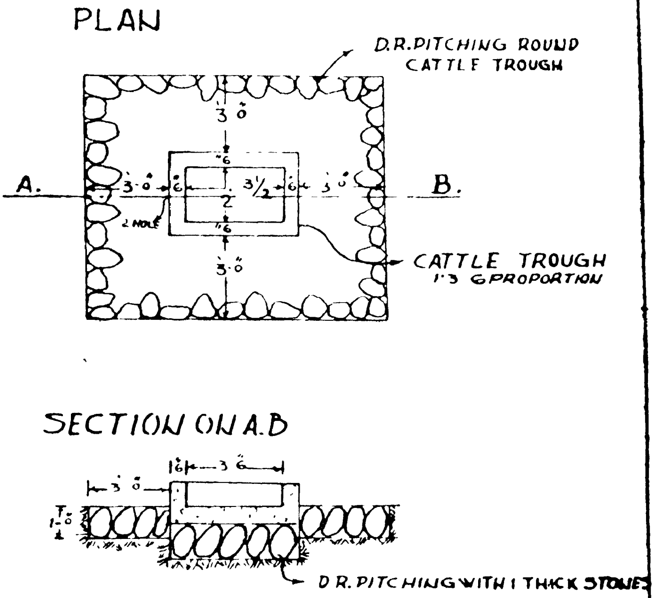


PHOTO PLATE NO. 16.—*Cattle also get their share of pure drinking water from the troughs provided by the side of wells.*

DESIGN OF CATTLE TROUGH

Scale : inch 6=feet



These plates are fixed on one of the inner panels, two feet below the parapet to be out of reach as it was observed that, when these were fixed on the outside of the parapet they were defaced by the mischievous village urchins.

Oiling the Pulleys.

The wells which are thus constructed are now ready in every respect for use, and before they are handed over to the village authorities, the contractors will pay a sum of anna one per well to the village authorities and obtain their receipts, which after being countersigned by the contractor, the sectional and subdivisional officers, are forwarded along with the final bills for payment to the contractors. This amount of anna one per well paid to the village authorities is intended to make a good beginning to keep the pulleys well-oiled. Subsequent charges for oiling are expected to be borne by the villagers. The patels are also impressed of the responsibility to keep the wells and its surroundings clean.

Handing over Wells.

Wells thus completed in all respects (except sterilised, blocked and filled up wells are handed over to the village authorities and signatures obtained on charge sheets in printed vernacular forms in triplicate (1) the original copy of which is given to the village Patel, (2) the counterfoil after the completion of the work in the taluq, is forwarded to the First Taluqdar's office (Local Fund Section) which will constitute the stock register of his office for these wells and (3) the triplicate copy is recorded in the Measurement book with the final measurements.

" Harijan wells " formerly classed as " Non-caste wells " which are intended to be accessible to all the sections of the Harijans are similarly handed over with a remark "Harijan well " without making any reference of the sub-castes.

A translated copy of the receipt printed in triplicate in vernacular language is shown below.

Counterfoil	Original	Triplicate
Book No. . . . . No. . . . . WELL SINKING DEPARTMENT District. . . . . Village. . . . . Taluq. . . . . It is certified the following wells have been handedover to me in good condition to-day. . . . . D/. . . . . and depths of water as noted in wells are given below. New wells Depth of water. Remodelled wells. . . . . Wells for Harijans. . . . . The rules regarding the upkeep and safe custody of wells printed on the reverse of the form, have been read out and explained in detail by Mr. . . . . *Signature of Police Patel.* *Signature of Mali Patel.* Signature of officer handing over charge, Well Sinking Department		

Rules Printed in English on the reverse of the counterfoil, and in Vernacular Languages in the original and triplicate copies.

1. The Police patel is responsible for oiling the pulleys with castor-oil twice weekly or whenever necessary.

2. He is responsible for the fabric of the well and must prevent the parapet and platform from being chipped or

wilfully damaged, prevent cattle and horses from getting on to the platform. He is responsible for seeing the platform and drain kept clean and the spill water runs away down the drain and the cattle trough not allowed to get choked. He must prevent dust and refuge being thrown down the well and should jawari stalks or other matter be thrown or fall into the well he is responsible that it is removed so that the water is not rendered foul thereby.

3. The area around the well up to 200 feet must be kept scrupulously clean and no manure allowed to be stacked or cattle stalled within 200 feet radius of the well, and any person found using the area around the well as a Latrine punished and if necessary reported to the Tahsildar, who will take necessary action.

4. He will report to the Tahsil, should any of the following things occur :—

i. Shortage of water in the well.

ii. Breaking of the pulley or damage to the pulley frame or fabric of the well.

iii. If the rock below the cement lining starts to break away or fall down the well.

The police patel is hereby warned that serious notice will be taken if these rules are not obeyed.

The Well Sinking Department exercises supervision of these wells, until it moves to another area.

The subdivisional officers are to submit monthly statements of wells handed over in their subdivisions, so as to reach the Special Officer within the 10th of the subsequent months in the following forms.

Serial No.	Name of well	Date of handing over	Type of well	No. of pulleys	Total depth from parapet	Depth of water	Final Srl. No.
1	2	3	4	5	6	7	8

The inhabitants of the village who are benefited by the use of Government wells are impressed with the idea of replenishing the earthworks round the platforms, drains and cattle troughs periodically which they can easily get done at practically no cost.

The Tahsildars and the Local Fund Engineers who tour these parts should make it their duty to inspect these wells and report their condition to the First Taluqdar (Mir Majlis) and the Special Officer in charge, Well Sinking Department.

The use of Harijan wells by all the Harijan sub-sects is advocated, and the Heads of Police, Medical, Co-operative, Customs, Education and Excise Departments are requested to make propaganda to this effect.

Abandoning of Wells.

The trial pits excavated for investigation as well as wells which are abandoned due to causes mentioned below, form receptacles for the storage of rain water which, in course of time, get foul, proving injurious to public health. To put a stop to this the trial pits and abandoned wells are refilled with available excavated material. A rate of Rs. 5-0-0 per thousand cubic feet is allowed for the refilling. It is however gratifying to note that of late very few trial pits are sunk in the investigation of groundwater supply, as the department is now in a position to tackle this problem of groundwater because of the experience gained by long years of work in this direction. The abandoning of wells in a few cases was due to the (1) meeting of unfavourable geological strata or (2) saline water.

Water Analyses.

In the latter case the water is analysed to find out the percentage of sodium chloride (NaCl) and also free ammonia, nitrites and nitrates. To conduct this test, the sectional officers are provided with portable deal-wood boxes measuring 9″ × 3″ × 3″ with sliding covers, containing the following :—

i. A glass graduated cylinder on foot with spout to measure from 1 to 50 c.c. with minor graduations.

ii. One glass rod 8 inches long.

iii. One tube potassium chromate of 25 tabloids of Burroughs & Wellcome Co.

iv. Half a dozen tubes of Silver Nitrate of 25 tabloids in each tube of Burroughs & Wellcome Co.

v. A booklet of instructions.

The saline water is analysed in the following manner.

I. *Colour and Turbidity.*—The jar after being cleaned with the water that is to be tested, is filled up to 50 c.c. mark and placed on a white sheet of paper. By looking down the jar any colour or turbidity present is noted.

II. *Odour.*—Some waters emanate a foul smell which can be perceived by the smell, but others emit foul smell only after they are vigourously shaken. The jar is half-filled with water, and the mouth covered with the palm of the hand that has been previously washed with the water that is to be tested, and shaken vigourously. The odour is then noted after removing the palm of the hand.

III. *Taste.*—Waters which are too foul and contain deleterious minerals are not safe to be tasted, but those which could be safely tasted will give a rough idea of the nature of the dissolved impurities. Waters can be classified as (1) Sweet, (2) Insipid or tasteless, (3) Brackish or bitter, and (4) Saline.

In order to test the water for chlorine a measured quantity of the sample, say 25 c.c. is taken in the jar provided, and $\frac{1}{4}$ to $\frac{1}{2}$ tabloid of potassium chromate is added and gently crushed with the glass rod in order to dissolve the substance. This would impart an yellowish colour to the liquid. Form $\frac{1}{4}$ to $\frac{1}{2}$ tabloid of Silver Nitrate ($AgNO_3$) is then added. If the reaction is not complete further additions of $\frac{1}{4}$ to $\frac{1}{2}$ tabloid is made by stages until the final reaction can be perceived, when the liquid assumes a permanent red colouration. The chromate added, acts as an indicator, which when turned into red shows the end of the reaction. The double decomposition taking place in the liquid may be expressed by the following equation.

$$AgNO_3 + NaCl = AgCl + NaNO_3.$$

The silver chloride being insoluble is precipitated and sodium nitrate remains in solution. Each tabloid of $AgNO_3$ corresponds to 2 parts of chlorine per 100,000. For instance if 25 c.c. were taken to conduct the test and if 4 half tabloids were used to complete the reaction, then it means that 2 complete tabloids were used which would be equivalent to $2 \times 4 = 8$ tabloids for 100 c.c. of the liquid taken. As each tabloid represents 2 parts of chlorine, the equivalent for 8 tabloids will be $8 \times 2 = 16$ parts of chlorine in 100,000. This when expressed in percentage would equal to 0.016 per cent. As most of the chlorine in water is in a combined state as

sodium chloride NaCl, the above result can be expressed in terms of NaCl by dividing the result by 0.6, *i.e.*, 0.016/0.6 =0.026 per cent.

The results are then finally tabulated as follows:

i. Colour.	*iv.* Taste.
ii. Turbidity.	*v.* Chlorine.
iii. Odour.	*vi.* Equivalent of NaCl.

In order to effect economy in the use of these tabloids, the amount of c.c. of water taken for the test may be reduced. For instance instead of 50 c.c., or 25 c.c. 12 1/2 c.c., may be taken and silver nitrate tabloids, cut to quarter parts, are added. Though this method would certainly result in some error in the percentage of chlorine or its equivalent in NaCl, still from a consideration of the tests being carried out in out of the way and far off places even from the so-called small towns or cities, it is considered enough for all practical purposes in arriving at a near correct estimate of its amount. Suppose the number of tabloids added to complete the reaction of 12 1/2 c.c. of the sample is say, about 60. This means $\frac{60}{4}=15$ full tabloids for 12 1/2 c.c. or $15\times8=120$ tabloids for 100 c.c. This would be equivalent to $120\times2=240$ parts in 100,000, and the percentage, therefore, would work out to 0.240 per cent chlorine which will be equivalent to $\frac{0.240}{0.6}=0.40$. per cent. of NaCl (or 400 parts in 100,000). Instead of using 120 tabloids by taking 100 c.c. of the sample, it can be reduced to one eighth the quantity by taking lesser volume of the sample of 12 1/2 c.c.

Potability of Saline Water.

The basis of potability of saline waters depends upon the local conditions and also according to the local standards of taste (which are usually found out from enquiry of the villagers themselves). In areas where no sweet waters can be tapped due to excessive inherent salinity and deep seated nature besides the superficial salinity caused by the decomposition and decay of soils, etc. waters which have shown as high as 0.112 per cent. of chlorine or 0.186 of NaCl equivalent (or 186 parts in 100,000) have been passed for drinking in areas above-mentioned. In certain other parts of the same areas, waters containing as low as 0.062 per cent. of chlorine or 0.103 per cent. of NaCl (or 103

parts in 100,000) have also been passed for drinking purposes. The safe permissible limit is fixed at 0.05 per cent. of chlorine or 0.083 per cent. of NaCl, which means 83 parts in 100,000. A comparison of the figures given on page 26 showing the amount of common salt (NaCl) that affects the water for drinking purposes with those of the above figures may be found interesting.

The presence of free ammonia or nitrites or nitrates which are mainly due to contamination of decomposed organic or vegetable matter, is safely avoided by selecting well sites far away from the influence of such contamination and outside the village precincts

Accidents.

Accidents are liable to occur due to the following causes. (1) Mishandling of explosives, (2) Blasting by unskilled and unauthorised blasters, (3) Improper handling of misfires, (4) Caving of sides, (5) Collapse of mhots, (6) Fall of muck or boulders that are hauled, (7) Slipping or falling of workmen, and (8) Accumulation of exhaust gases in the well.

I. The precautions that are adopted in the handling and use of the explosives are dealt with in detail in page 201.

II. Blasting is done only by skilled and licensed blasters as discussed in page 200.

III. Proper handling of misfires has been described in detail in page 203.

IV. The prevention of the caving of sides is dealt with in detail in page 208.

V. Strong and stable mhots are only to be constructed as dealt in page 209.

VI. Extra precautionary measures are adopted in hoisting or lowering of materials by the use of specially constructed iron buckets as shown in the sketch in the next page. These buckets are manufactured in the departmental workshop which may be purchased by the contractors or obtained from firms. In addition, the workmen in the well are advised to wear a padded tin helmet so that if, by chance anything falls on their heads they may not be seriously injured.

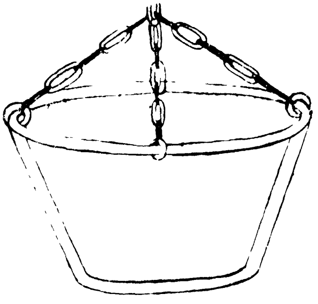


Fig. 31

VII. Workmen, while getting into or out of the well by rope ladders or the mhot rope are securely tied round their waists and shoulders by loop of rope one end of which is held by the men on top as a measure of further safety. A better and safer method advocated is the use of wooden cradle for lowering and hauling workmen (see sketch at the side).

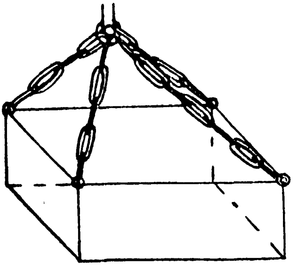


Fig. 32

VIII. The details as to how exhaust gases have to be directed to the surface, and when the workmen get down into the wells in which pumps have been installed and worked are given elsewhere.

Equipment

It is insisted that the following materials are to be kept at the site of each well.

1. Nippers or Pliers.
2. Knife.
3. ½″ Copper rod or pipe 3′ long.
4. Wooden hammer.
5. Red flags small one to be fixed inside the well should there be a misfire, and big one to be fixed outside, to caution the people at the surface.
6. Spare steel axle for mhot pulleys.
7. Padded tin helmets.
8. Loop of ropes for use above mentioned.
9. Tin exhaust pipes at least 3 of 10 feet each, in cases of excavation of deep wells.
10. Register showing the daily receipts, issues and balances of explosives.
11. Register showing the number of bores drilled and fired, the number of explosions heard and the number of misfires if any.

In spite of all the precautions mentioned above and pamphlets circulated for information in all the vernacular languages to all the parties concerned, serious injuries and in very rare and exceptional cases deaths have occurred, mainly due to the indifference and negligence of the workmen not scrupulously following these precautionary measures.

It is made obligatory on the part of contractors that irrespective of the nature of injuries sustained, the injured persons are to be given an injection of anti-tetanus immediately they are removed to the nearest civil dispensary. Stocks of anti-tetanus are kept with each sectional officer which are delivered to the contractors as required by them.

All accidents are to be reported immediately direct to the Superintending Engineer, Well Sinking Department either by the Subdivisional or Sectional Officers who may get first information, forwarding a copy of the report to the office of the Special Officer. The procedure adopted in reporting the accidents is as follows :

W.S.D. Form No. 54

No............... *Date*...............13 F.

From

....

Sectional Officer, Well Sinking Department.

Camp..................District...............

P. O....................Taluq......................

To

The Superintending Engineer, Well Sinking Department, Hyderabad-Deccan.

Subject.—Accident on..................well at........ ....village in Block........................of ....Taluq.

Sir,

I beg to inform you (name of person)................ reported to me on (date)......................at (time) ....while I was at (place)............ that an accident had occurred on (name of well and village) ....of Mr................ Contractor. Immediately I proceeded to the spot, where I reached at (time)...................on (date).......... On enquiry I learnt that on (date).................. while (nature of work).................... was in pro-

gress in the well (give shortly the circumstances under which the accident took place).............................
....
....
....
....
resulting in...
... .

I beg to remain
Sir,
Your most obedient servant,
Sectional Officer.

No......................... Date.....................

Copy forwarded to the Subdivisional Officer, Well Sinking Department.........................for information.

Signature.

The other details of the accident are given in the form as below :

1. Did the accident arise out of and in the course of employment of the contractor ?	
2. Were the workmen at the time under the influence of drink or drugs ?	
3. Was there wilful removal or disregard by the workmen of any safety, guard or other device which was known to have been provided to secure the safety of the workmen ?	

	Name	Age	Profession	Wages	Details of injuries
4. Particulars of persons involved in the accident ..					

5. Were the injured sent to a Doctor ? If so to whom and where ? If not why ?

6. Result of Panchanama by Police authorities

	Relations or dependents of the dead			
	Name	Relation-ship	Age	Address
7. Name of the dead				

	Name	Property
8. Extent of personal property of the deceased or injured if any		

Sectional Officer.

No............ Date....................

Copy forwarded to the Special Officer in-charge, Well Sinking Department.........................for information.

Sectional Officer.

After receipt of the above in this office a statement in the form below is sent again to the Superintending Engineer, with recommendations for compensation as enforced by the Compensation Act No. 6 of 1349 Fasli (1940), as portions thereof given elsewhere below (page 256).

W.S.D. FORM No. 54 A.

H.E.H. THE NIZAM'S WELL SINKING DEPARTMENT.

Details of Accident.

1. Date and time of Accident

2. Place at which accident occurred

3. Name of the contractor of the well.

4. Nature and cause of accident and detailed statement of the circumstances in which it happened.

5. Did the accident arise out of and in the course of employment of the contractor ?

6. Were the workmen at the time under the influence of drug or drink ?

7. Was there wilful removal or disregard by the workmen of any safety guard or other device which was known to have been provided to secure the safety of the workmen ?

	Name	Age	Profession	Wages	Details of injuries
8. Particulars of person involved in the accident ..					

9. Were the injured sent to a Doctor ? If so to whom and where ? If not why ?				
10. Result of Panchanama by Police authorities				

	Relations or dependents of the dead			
	Name	Relationship	Age	Address
11. Name of persons dead				

	Name	Property
12. Extent of personal property of the deceased or injured if any ?		

	Name	Compensation
13. Amount of compensation recommended by the Special Officer		

Special Officer i/c,
Well Sinking Department.

Recommendations of the Superintending Engineer, Well Sinking Department, Hyderabad-Deccan.

Workmen's Compensation Act.

The Compensation Act No. 6 of 1349, Fasli (1940), came into force from Shehrewar 1349 Fasli (July 1940), and works which were let out after the above date, payment of compensation by the contractors was made obligatory and a clause to the above effect was incorporated in the Agreement Bond as follows :

" I will be responsible for the payment of compensation according to the Workmen's Compensation Act No. 6 of 1349 F., or its modifications from time to time in case of accidents to the workmen under my employment."

Some relevant portions of the Act with slight modifications as approved by the Commerce and Industries Department, in connection with the accidents occurring during excavation of wells by this department are given below :

Workmen's Compensation Act No. 6 of 1349 F. (1940)	*Modifications.*
(*e*) "dependents" means any of the following relatives of a deceased workman namely : 1. A widow. 2. A minor legitimate son. 3. A minor legitimate daughter. 4. Widowed mother and if wholly or in part dependent on the earnings of the workman at the time of his death. 1. A widower. 2. A parent other than a widowed mother. 3. A minor illegitimate son. 4. An unmarried illegitimate daughter. 5. A daughter legitimate or illegitimate if married and a minor or if widowed. 6. A minor brother. 7. A widowed sister-in-law (brother's widow). 8. An unmarried or widowed sister.	Section 2 Clause (*e*) of the Compensation Act has classified dependents into two classes. Monies may be advanced up to Rs. 100 in aggregate to dependents of the first class without calling for any proof whether the dependents of the first class were wholly or in part dependent on the earnings of the workman at the time of his death. Dependents of the first class are (1) Wife, (2) a minor legitimate son. (3) a minor legitimate daughter, or (4) a widowed mother. But in case of dependents of the second class which consists of 11 persons (as mentioned subsequently in Section 2 Clause (*e*), Rs. 100 in the aggregate cannot be advanced to such depen-

9. A widowed daughter-in-law.

10. A minor child of a deceased son or daughter.

11. Where no parent of the workman is alive, a paternal grandparent.

ents without proof that all or any of such dependents were actually depending upon the earnings of the workman at the time of his death. As the Commissioner may at the time of hearing the case decides that any dependent of the deceased was not depending upon the workman at the time of his death and may disallow any advance that may have been paid, the advances to the dependents of the second class should therefore be made with a careful enquiry keeping in view of the above facts.

Section 10 *of the Act. Distribution of Compensation.*

(1) No payment of compensation in respect of a workman whose injury has resulted in death, and no payment of a lumpsum as compensation to a woman or a person under a legal disability shall be made otherwise than by deposit with the Commissioner, and no such payment made directly by an employer shall be deemed to be a payment of compensation.

Provided, that in the case of a deceased workman, an employer may make to any dependent advances on account of compensation not exceeding an aggregate of one hundred rupees and so much of such aggregate as does not exceed the compensation payable to that dependent shall be deducted by the Commissioner from such com-

The Special Officer, Well Sinking Department may make payment of Compensation for injuries to a workman not resulting in death. He need not approach the Commissioner or any Officer appointed to perform his duties for making such payment (Section 10).

In the case of injuries resulting in death the Special officer has to approach the Commissioner or the officer appointed to perform his duties, and make payment of compensation to the dependents of the deceased workman through the Commissioner (Section 10).

But the Special Officer, Well Sinking Department

pensation and repaid to the employer.

(2) Besides the conditions mentioned in Clause (1) Section 10, any other sum amounting to not less than ten rupees which is payable as compensation may be deposited with the Commissioner on behalf of the person entitled thereto.

3. The receipt of the Commissioner shall be a sufficient discharge in respect ofany compensation deposited with them.

(4) On the deposit of any money under Clause (1) as compensation in respect of a deceased workman the Commissioner shall deduct therefrom the actual cost of the workman's funeral expenses, to an amount not exceeding twenty-five rupees and pay the same to the person by whom such expenses were incurred.

And shall if he thinks necessary, cause notice to be published or to be served on each dependent in such manner as he thinks fit, calling upon the dependents to appear before him on such date as he may fix for determining the distribution of compensation.

If the Commissioner is satisfied after any enquiry which he may deem necessary, that no dependent exists he shall repay the balance of the money to the employer by whom it was paid.

The Commissioner shall, on application by the employer, furnish a statement showing in detail all disbursements made, can make an advance of Rs. 100, in the aggregate to such dependents of the deceased workman as are mentioned in Paras 1 and 2 above (Section 10).

In cases where contractors have been entered into prior to the passing of this Act, the total compensation payable to the dependents will be divided for payment by ¼th payable by the contractors and ¾ths payable by the Government as mutually arranged between the Special Officer and the contractors concerned.

(5) Compensation deposited in respect of a deceased workman shall subject to any deduction made under Clause (4), be appropriated among the dependents of the deceased workman or any of them in such proportion as the Commissioner thinks fit or may in the discretion of the Commissioner, be allowed to any one dependent.

(6) Where any compensation deposited with the Commissioner is payable to any person the Commissioner shall, if the person to whom the compensation is payable is not a woman or a person under a legal disability, and may, in other cases pay the money to the person entitled thereto.

(7) Where any lumpsum deposited with the Commissioner is payable to a woman or a person under a legal disability, such sum may be invested, applied or otherwise dealt with for the benefit of the woman, or such person during his disability, in such manner as the Commissioner may direct.

Where a half-monthly payment is payable to any person under a legal disability the Commissioner may, of his own motion or on an application made during the disability, to any dependent of the workman or to any other person whom the Commissioner thinks best fitted to provide for the welfare of the workman.

(8) Where, on application made to him in this behalf or otherwise, the Commissioner

is satisfied that, on account of neglect of children on the part of a parent or on account of the variation of the circumstances of any dependent or for any other sufficient cause, an order of the Commissioner as to the distribution of any sum paid as compensation or as to the manner in which any sum payable to any such dependent is to be invested, applied or otherwise dealt with, ought to be varied, the Commissioner may make such orders for the variation of the former order as he thinks just in the circumstances of the case.

Provided that no such order, prejudicial to any person, shall be made unless such person has been given an opportunity of showing cause, why the order should not be made, or shall be in any case in which it would involve the repayment by a dependent of any sum already paid to him.

(9) Where the Commissioner varies any order under Clause (8) by reason of the fact that payment of compensation to any person has been obtained by fraud, impersonation or other improper means, any amount so paid to or on behalf of such person may be recovered in the manner hereinafter provided in Section 37.

Section 37. Recovery.

The Commissioner may recover as an arrear of land-revenue any amount payable by any person under this Act, whether under an Agreement for the payment of compensation or otherwise.

Section 6 of the Act. Amount of Compensation.

Subject to the provisions of this Act, the amount of compensation shall be as follows, namely :—

A. Where death results from injury :—

(I) in the case of an adult in receipt of monthly wages falling within limits shown in the first column of Schedule IV., the amount shown against such limits in the second column thereof, and

(II) in the case of a minor—two hundred rupees.

B. Where permanent total disablement results from the injury :—

(*i*) in the case of an adult in receipt of monthly wages falling within limits shown in the first column of Schedule IV—the amount shown against such limits in the third column thereof, and

(*ii*) in the case of a minor—twelve hundred rupees.

C. Where permanent partial disablement results from the injury,

(*i*) in the case of any injury specified in the Schedule I, such percentage of the compensation as would have been payable in the case of permanent total disablement as is specified therein, as being the percentage of the loss of earning capacity caused by that injury, and,

(*ii*) in the case of an injury not specified in Schedule I. such percentage of the compensation payable in the case of permanent total disablement as is proportionate to the loss of earning capacity permanently caused by the injury.

Explanation

Where more injuries than one are caused by the same accident, the amount of compensation payable under this head shall be aggregated but not so, in any case as to exceed the amount which would have been payable if permanent total disablement had resulted from the injuries.

D. Where temporary disablement, whether total or partial, results from the injury a half-monthly payment payable on the sixteenth day after the expiry of a waiting period of seven days from the date of disablement and that, after half-monthly, during the disablement or during a period of five years.

(*i*) in case of an adult in receipt of monthly wages falling within limits shown in the first column of the Schedule IV—of the sum shown against such limits in the fourth column thereof, and

(*ii*) in the case of a minor—of one-half of his monthly wages, subject to a maximum of thirty rupees.

Provided that,

(*a*) there shall be deducted from any lumpsum or half-monthly payments to which the workman is entitled, the amount of any payment or allowance which the workman has received from the employer by way of compensation, during the period of disablement prior to the receipt of such lumpsum or of the first half-monthly payment, as the case may be, and

(*b*) fortnightly payments of compensation will not in any case exceed the difference between half the wages of the employee which he was getting before the accident and half of the wages which he is getting after the accident.

E. On the ceasing of the disablement before the date on which any half-monthly payment falls due, these shall be payable in respect of that half-month a sum proportionate to the duration of the disablement in that half-month.

Method of calculating wages.

Section 7.—For the purposes of Section 6, the monthly wages of a workman shall be calculated as follows, namely :

(*a*) where the workman has, been in the service of the employer who is liable to pay compensation, the monthly wages of the workman shall be one-twelfth of the total wages which have fallen due for payment to him by the employer in the last twelve months preceding the date of accident.

(*b*) where the whole of the continuous period of service immediately preceding the accident during which the workman was in the service of the employer who is liable to pay compensation was less than one month, the monthly wages of the workman shall be deemed to be the average monthly amount which, during the twelve months immediately preceding the accident, was being earned by a workman employed on the same work by the same employer or, if there was no workman so employed, by a workman employed on similar work in the same locality ;

(*c*) in other cases, the monthly wages shall be thirty times the total wages earned in respect of the last continuous period of service immediately preceding the accident from the employer who is liable to pay compensation divided by the number of days comprising such period.

Explanation.—A period of service shall, for the purposes of this Section, be deemed to be continuous which has not been interrupted by a period of absence exceeding fourteen days.

SCHEDULE I.

SECTIONS 2 AND 6.

List of injuries deemed to result in permanent partial disablement.

Serial No.	Injury	Percentage of loss of earning capacity
1	Loss of right arm above or at the elbow ..	70
2	Loss of left arm above or at the elbow ..	60
3	Loss of right arm below the elbow	60
4	Loss of leg at or above the knee	60
5	Loss of left arm below the elbow	50
6	Loss of leg below the knee	50
7	Permanent total loss of hearing	50
8	Loss of one eye	30
9	Loss of thumb	25
10	Loss of all toes of one foot	20
11	Loss of one Phalanx of thumb	10
12	Loss of index finger	10
13	Loss of great toe	10
14	Loss of any finger other than index finger ..	5

NOTE.—Complete and permanent loss of the use of any limb or member referred to in this Schedule shall be deemed to be the equivalent of the loss of that limb or member.

SCHEDULE IV.

SECTION 6.

Compensation payable in certain cases.

MONTHLY WAGES OF THE WORKMAN INJURED		AMOUNT OF COMPENSATION FOR		Half-monthly payment as compensation for temporary disablement of adult
More than	But not more than	Death of adult	Permanent total disablement of adult	
Rs.	Rs.	Rs.	Rs.	Half his mohthly wages Rs.
..	10	500	700	..
10	15	550	770	5 0 0
15	18	600	840	6 0 0
18	21	630	882	7 0 0
21	24	720	1,008	8 0 0
24	27	810	1,134	8 8 0
27	30	900	1,260	9 0 0
30	35	1,050	1,470	9 8 0
35	40	1,200	1,680	10 0 0
40	45	1,350	1,890	11 4 0
45	50	1,500	2,100	12 8 0
50	60	1,800	2,520	15 0 0
60	70	2,100	2,940	17 8 0
70	80	2,400	3,360	20 0 0
80	100	3,000	4,200	25 0 0
100	200	3,500	4,900	30 0 0
200	..	4,000	5,600	30 0 0

Considering the nature of the work of well sinking which is fraught with danger, the fatal accidents are indeed low, as is evident from the figures given below, from Khurdad 1343 F. to end of 1351 F. (April 1934—September 1942 A.D.).

Total number of works completed during the period =2,962.

Accidents : 2.19 (of which 0.91 deaths and 1.28 injured) for every 100 works completed.

3.18 deaths per year.

4.47 injured per year.

These are deeply regrettable and every effort is being made to minimise them as far as possible.

In order to arrive at the premium for insuring the labour working under the contractors, the following details were obtained from them :—

Year	Total amount of wages paid as per statement of the contractors	Total amount drawn by the contractors excluding stock
1941	2,24,000	5,31,293
1942	2,87,210	6,73,567

Incidentally it is observed that, the percentage of labour charges on the total amount of work done, works out to :

Year	Including stock charges	Excluding stock charges
	Per cent.	Per cent.
1941	34.11	42.16
1942	38.43	42.64

Thus the labour charges and the cost of explosives works out to an average of about 70 per. cent on

Total stock charges	Total amount of work done columns 3 & 4	Amount of compensation paid on the accidents	PERCENTAGE OF COMPENSATION ON ITEMS	
			2 & 4	
1,25,299	6,56,592	6,162	2.75	1.16
73,692	7,47,259	4,130	1.43	0.61
Average ..	..	..	2.09	0.88

the cost of the work without stock charges, leaving a balance of 30 per cent. towards cost of steel, ropes, hire on moulds and pumps, etc., running and replacement of parts of the pumping plant, erection of mhots, travelling charges. transportation of materials, interest on capital investment, compensation to labour towards accidents and lastly the contractors profit.

In the above percentage of expenditure excepting for labour charges, the other items are materially affected due to war conditions, thus affecting the financial stability of the contractors.

(It may be noted that against an expenditure of 2.75 and 1.43 per cent. as noted in column 4 of the above statement 7 per cent. is the premium charged by an insurance firm towards the compensation for accidents.

AMOUNT OF WORK DONE UP TO END OF 1352 FASLI (SEPTEMBER 1943 A.D.).

The number of wells sunk from the inception of the department (*i.e.*, from Khurdad 1337 F. to end of 1352 F.—April 1928 to end of September 1943 A.D.) with their average cost, etc., are given below :—

Raichur District.—In this district including Gurgunta Samasthan the operations of the department were first started in Khurdad 1337 F. (April 1928 A.D.). A total number of 1535 works of which 1259 are major, *i.e.*, new wells and old wells remodelled into draw-wells, and 276 minor works such as blocking of steps, sterilisation, filling up of old wells, were completed in 599 villages comprising a total population of 6,12,525 inhabitants, at a cost of Rs. 15,92,721–7–3$\frac{1}{6}$ which works out to one well for every 490 persons or 2.10 wells for every village. The average cost of a well of an average depth of 32.06 feet works out to Rs. 826-9-10 in this district as shown in the statement below :—

[*Statement.*

Raichur District.

Year	Number of wells completed		Major wells		Average cost excluding establishment charges	Percentage of establishment charges
	Major	Minor	Average depth from G.L.	Average height from steining		
					Rs.	
1929 ..	90	2	20'.80	13'.70	1,265	63'.5
1930 ..	79	..	23'.40	14'.20	1,291	50'.4
1931 ..	202	2	30'.00	17'.80	794	35'.4
1932 ..	104	15	29'.80	24'.00	747	54'.8
1933 ..	104	21	31'.90	27'.22	815	62'.7
1934 ..	169	51	31'.25	26'.70	729	37'.2
1935 ..	273	115	35'.32	35'.21	725	28'.1
1936 ..	230	70	36'.64	36'.41	883	21'.7
1937 ..	1	..	37'.66	40'.72	207	24'.4
1942 ..	5	..	29'.90	33'.00	1,012	14'.8
1943 ..	..	..	32'.25	35'.50	1,022.14.11	17.5
Total ..	1,257	276	..	..	..	..
Average	..	..	32'.06	27'.97	826.9.10	..

Gulbarga District.—The work in this district (including Afzalpur Paigah) was started in Bahman 1345 F. (December 1935 A.D.) where a total number of 1634 works of which 1294 are major and 340 minor works were completed to end of 1351 F. (September 1942 A.D.) at a cost of Rs. 21,23,730-10-5½ in 730 villages with a population of 6,36,951 inhabitants. This works out to one well for every 492 persons and 1.77 wells for every village.

[*Statement*,

Gulbarga District.

Year	Number of wells completed		Major wells		Average cost excluding establishment charges		Percentage of establishment charges
	Major	Minor	Average depth from G.L.	Average height of steining from parapet	Major	Minor	
1936 ..	71	32	32 .07	34 .60	855 5 8	21 9 0	21.7
1937	237	106	37 .43	37 .48	1,138 9 0	23 5 3	24.4
1938 ..	277	70	45 .24	45 .72	1,507 11 0	22 8 10	18.4
1939 ..	264	50	45 .64	47 .09	1,507 15 0	26 4 0	20.6
1940	270	54	45 .26	41 .71	1,480 0 0	18 8 0	17.2
1941	54	16	46 .23	47 .04	1,638 9 3	16 11 1	14.9
1942 ..	63	2	46 .00	48 .48	1,784 10 5	34 11 0	14.8
1943 ..	58	10	53 .83	46 .27	2,240 10 8	7 4 4	17.5
Total ..	1294	340	..	..	..	..	..
Average	..	..	43 .64	43 .33	1,450.5.9	21.15.2	..

Osmanabad District.

The department shifted to Osmanabad in Khurdad 1349 F. (April 1940 A.D.) where 825 wells were proposed in 311 villages of Tuljapur and Parenda taluqs, with a population of 2,10,287 inhabitants, which from the number of wells so far completed would work out to one well for every 424 persons and 1·60 wells for every village. By the end of 1352 F. (September 1943 A.D.) 601 works of which 496 are major and 105 minor wells were completed, the details of which are given below :

[*Statement.*

Osmanabad District.

Year	Number of wells completed		Major wells		Average cost excluding establishment charges		Percentage of establishment charges
	Major	Minor	Average depth from G.L.	Average height of steining from parapet	Major	Minor	
					Rs. A. P.	Rs. A. P.	
1940 .	24	13	39 81	43 02	1,368 5 0	23 15 7	17.2
1941 ..	187	41	44 .30	43 21	1,870 2 8	19 9 0	14.9
1942 ..	219	42	55 71	42 81	2,578 12 0	22 11 8	14.8
1943 ..	66	9	49 .97	32 .10	2,131.5.5	40.11. 0	17.5
Total ..	496	105	.	..	..	..	..
Average	..	..	49 88	41 .54	2,193.6.6	23.2.11	..

Bhir District.

Year	Major	Minor	Average depth from G.L.	Average height of steining from parapet	Major	Minor	Percentage of establishment charges
1941	1	..	28 .50	32 .00	965 1 4	..	..
1942 ..	23	.	41 48	40 00	1,634 0 0	..	..
1943 ..	83	.	49 .89	39 .79	2,470.1.2	..	17.5
Total ..	107	..	.	..	..	..	..
Average	..	.	47 .88	39 .68	2,276.4.6	..	..

Wells in Jagirs and Paigahs.

For reasons mentioned already wells which are included in the above statements are provided in jagirs and paigahs situated within the famine zone. In order to facilitate the completion of wells in these areas along with the normal works of the department, the Government have granted a system of long-term loans at a nominal rate of interest of 2 per cent. per annum to these estates,

PART V.

CHAPTER I.

Old Wells.

Remodelling of old Wells:—The methods of remodelling old wells are divided mainly into four classes as follows :

I. The old draw-wells of small sizes are widened to standard diameters and standardised to one of the four types of new wells already mentioned.

II. The old step-wells which possess good steining on all sides and have batters on their mhot sides not exceeding 6 feet, are remodelled by constructing an overhanging platform supported by reinforced cement concrete (R.C.C.) cantilevers with the necessary number of pulleys fixed at the end of the cantilevers. The steps in these cases are blocked by means of masonry walls 7 feet high. Standard designs are worked out for overhanging platforms with cantilevers of engths 2, 3, 4, 5 and 6 feet, the details of which are given in Appendix.

III. The old step-wells with steinings, the batters of which exceed 6 feet which are not strong enough to carry overhanging platforms, are remodelled by dismantling the steinings to the required depths and lengths and building C.R.S. masonry walls with vertical faces in their places and fixing the necessary number of pulleys on them. The steps are similarly blocked as in case II above. Sometimes if the situation warrants, pulleys are fixed on the walls which block the steps, there being sufficient depth of water below the pulleys during all the seasons of the year.

IV. Old step-wells which do not possess strong steining and which cannot be remodelled in either of the two ways mentioned above, are standardised to hexagonal or pentagonal wells with further sinkings, if necessary, and casting cement concrete lining in the centre of the well and filling around the lining.

As the old village wells are of various sizes and shapes no hard and fast rule can be adopted in their construction

to standard designs ; therefore each case has to be considered individually on its merits.

Details of Old Wells to be noted before being taken up for remodelling.

Before starting work on any old well, detailed sectional dimensions of it are taken, along with probable depth of silt and the nature of the soil at the bottom of the well from enquiry from the villagers. The total depth of the well from ground-level at different corners and bends is noted in addition to the depth at the mhot side, the classification of soils and the probable depth to which the well is to be further sunk. This information is passed on to the Special Officer for use at a later date when payments have to be made to the contractor. Invariably a rough estimate is prepared to compare the costs of remodelling to providing a new well and adopting cheaper of the two proposals.

Initial Bailing or De-watering.

The charges that are allowed for initial bailing is usually one day of 3 hours. Wherever de-watering of a well requires more than one day, the extra bailing charges are allowed in the following manner :

i. The cubical contents of the water in the well before pumping are worked out in gallons (Cubic feet $\times 6.25$).

ii. From the average recuperation of water in the well the amount of water collected during the time of pumping the water is calculated.

iii. Then the time required for bailing out the total amount of water (i) and (ii) is calculated. This depends on the capacity of the pump used. The average capacities of different pumps that are in use are as follows :—

Ford pump of 20 BHP. –15,000 gallons per hour.
Hamsworthy pump 4 BHP.—3,000 gallons per hour.
Lister pumps of 3 BHP.—2,000 gallons per hour.
Duetz pumps of 3 BHP. 2,000 gallons per hour.

Slush Removal.

After initial bailing is done the exact depth and size of well above the slush level are noted. The slush removed is thrown far away from the well in order to avoid contamination. Boulders if any, are removed and stacked on the top. These matters are then reported to the subdivisional officer with necessary sketches.

To face p. 275.

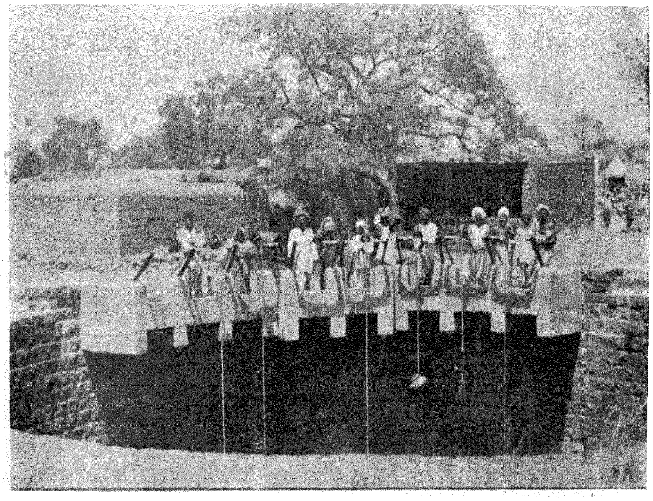


PHOTO PLATE NO. 17.—*An old step-well remodelled into a draw-well with overhanging platform.*

I. Remodelling old draw-wells of small sizes to standard sizes.—These wells are widened to standard diameter if necessary and further sinking carried on as in the case of new wells.

II. Remodelling by means of overhanging platforms.—The first thing that is noted is the length of the cantilever required and the side wherein to fix pulleys. The pulley side is to have strong steining and least batter— this will be found usually on the old mhot side of the well. In arriving at the length of the cantilever required, one of the deciding factors should be that when the pots are let down in the well, they should not touch the sides. From enquiry, any projection or ledge below water-level could be made out or the better method is to empty the well, and the length of the cantilever arrived at by dropping a plumb bob. After arriving at the length of the cantilever and the number of pulleys to be fixed, requisition is made to the Special Officer for supply of the required materials of reinforcement, etc. The R.C.C. cantilevers are cast on the ground and as close to the well with suitable shuttering and then moved to position. Over these the pre-cast slabs are laid to act as platform.

Design of R.C.C. cantilevers for different lengths.

Lengths of cantilevers	Lengths of bearings	Breadth of beams	Thickness of beams	Number of bottom rods	Number of stirrups
				Dia.	
6 feet ..	9′ 6″	0′ 9″	1′ 4″	2½	19
5 feet ..	8′ 6″	0′ 9″	1′ 1″	2½	18
4 feet ..	8′ 0″	0′ 9″	1′ 0″	2½	15
3 feet ..	6′ 6″	0′ 9″	0′ 10″	2½	11
2 feet ..	5′ 6″	0′ 9″	0′ 8″	2½	11

Cement Concrete Proportion.

For cantilever and the same produced over the ground as bearing 1 : 2 : 4.

Slab over the cantilever portion : 1 : 2 : 4.

Slab over the bearing portion : 1 : 3 : 6.

Platform wall : 1 : 3 : 6.

The general design with details is shown in the drawing enclosed in Appendix

After casting the beams and slabs, they are left for curing for at least three weeks.

The strength of the cantilevers and the stability of the overhanging platform depends on the efficiency with which casting and curing of these beams are done. Therefore it is necessary that the sectional or the subdivisional officer should be present when these are cast.

Before placing the cantilever in position one or two courses of old masonry are dismantled and rebuilt to the required length to serve as firm bedding for resting the cantilevers which are slowly shifted forward into proper position.

After the work on overhanging platform is completed, the steps of the well are blocked by building a masonry wall in cement mortar of 1 : 12 proportion. The height of the wall is maintained at 7 feet and constructed from such a level that the top of the wall is flush with top of the original steining of the well or ground-level. The width of the wall will be $1\frac{1}{2}$ feet without any filling on the back. Weep-holes are left at the bottom of the wall blocking the steps, to avoid any undue pressure of the rainwater collecting at its back. No coping is done or found necessary ; only cement plastering $\frac{1}{2}$ to $\frac{3}{4}$ inch thick is done. In some cases where wells are stepblocked people get down the well by means of the off-sets in the old steining of the well. In order to put a stop to it 4 or 5 off-sets above mean water-level are sloped off, else the idea of stepblocking is thereby defeated.

In the Tables below are given the different items of the R.C.C. overhanging platform, and (2) the number of cement bags required, and (3) weights of reinforcement.

[*Statement.*

STATEMENT SHOWING THE QUANTITIES OF DIFFERENT ITEMS

Of the R.C.C. Overhanging Platforms.

Serial Number	Length of cantilever	Length of bearing	Total of 2 & 3	Cubical contents on item No. 4	1 foot width of slab parallel to cantilevers in 1 : 2 : 4 over the cantilever portion 1' extra	One foot width of slab 1 : 3 : 6 over the balance of bearing portion + 1 ft. length of retaining wall to platform at right-angles to cantilever			Each pillar Cu. Ft.	Each landing pot wall Cu. Ft.	Each side parapet 6 inches thick Cu. Ft.	Each of the retaining walls at sides of the platform Cu. Ft.
						Slabs Cu. Ft.	Retaining Wall Cu. Ft.	Total Cu. Ft.				
1	2	3	4	5	6	7	8	9	10	11	12	13
1	2 Feet	5′ 6″	7′ 6″	3 75	1 00	1 50	0 11	1 61	2.000	0.58	2.00	0.46
2	3 Feet	6′ 6″	9′ 6″	5 94	1 33	1 83	0 11	1 94	2.000	0 58	3.00	0.57
3	4 Feet .	8′ 0″	12′ 0″	9 00	1 67	2 33	0 11	2 44	2.000	0 58	4 00	0 74
4	5 Feet .	8′ 6″	13′ 6″	10 97	2 00	2 50	0.11	2 61	2.000	0 58	5.00	0.80
5	6 Feet .	9′ 6″	15′ 6″	15 50	2 33	2.83	0.11	2.94	2 000	0 58	6.00	0.91

II.—STATEMENT SHOWING THE NUMBER OF CEMENT BAGS REQUIRED FOR

Serial No.	Length of cantilever	EACH BEAM			ONE FOOT WIDTH OF SLAB			ONE FOOT WIDTH OF SLAB PARALLEL TO CENTERING + ONE FOOT LENGTH OF RETAINING WALL TO PLATFORM AT RT. ANGLES TO CANTILEVER 1 : 3 : 6		
		For Concreting	For ½″ plastering	Total	For concreting	For ½″ plastering	Total	For concreting	For ½″ plastering	Total
1	2	3	4	5	6	7	8	9	10	11
1	2 Feet .	0.75	0.25	1.00	0.24	0.01	0.25	0.20	0.05	0.25
2	3 Feet	1.00	0.33	1.33	0.24	0.01	0.25	0.25	0.08	0.33
3	4 Feet	1.50	0.50	2.00	0.31	0.02	0.33	0.33	0.17	0.50
4	5 Feet .	2.00	0.50	2.50	0.42	0.08	0.50	0.33	0.17	0.50
5	6 Feet .	2.75	0.75	3.50	0.42	0.08	0.50	0.36	0.14	0.50

DIFFERENT ITEMS OF THE R.C.C. OVERHANGING PLATFORM.

Each pillar			Each landing pot wall			Each side parapet 6″ thick 1 : 3 : 6			Each of the retaining walls at sides of the platform		
For concreting	For ½″ plastering	Total	For concreting	For ½″ plastering	Total	For concreting	For ½″ plastering	Total	For concreting	For ½″ plastering	Total
12	13	14	15	16	17	18	19	20	21	22	23
0 40	0 10	0 50	0 10	0 025	0 125	0 25	0 08	0 33	0 055	0 045	0.10
0 40	0 10	0 50	0 10	0 025	0 125	0 40	0 10	0 50	0 067	0 050	0 125
0.40	0.10	0.50	0 10	0 025	0 125	0 50	0 25	0 75	0 089	0 078	0.170
0 40	0.10	0 50	0.10	0 025	0 125	0 63	0.37	1.00	0.130	0 120	0 250
0.40	0.10	0.50	0 10	0 025	0.125	0.72	0 28	1.00	0.140	0.110	0 250

STATEMENT SHOWING THE WEIGHTS OF REINFORCEMENT REQUIRED FOR THE DIFFERENT ITEMS OF THE R.C.C. OVERHANGING PLATFORMS.

Serial No.	Length of cantilever	Each beam Lbs.	Each panel of slab centre to centre of pillars	Each landing pot wall Lbs.	Each pillar Lbs.	Two ends of slab each 6″ wide with retaining walls Lbs.	Side parapets Lbs.
1	2	3	4	5	6	7	8
1	2 Feet ..	26	13 00	2.50	3.00	14.00	5.00
2	3 Feet ..	30	16.50	2.50	3.00	17.50	7.50
3	4 Feet ..	41	21.00	2.50	3 00	22 50	9.50
4	5 Feet ..	54	23 50	2.50	3.00	26.00	12.00
5	6 Feet ..	61	26.50	2.50	3.00	28.50	14.50

IV. Remodelling old step-wells into standard cement concrete wells.

After slush removal and further sinking where necessary, cement concrete lining is built just as in the case of new wells. To start with, boulder filling is done all round the lining to a height of 10 feet from the bottom or the spring level whichever is lesser, as explained under new wells. Above this, available mooram or earth filling is done. Sand, if available nearby, and if it works out cheaper to carry to the workspot, is preferred for filling behind the lining.

If the filled up soil sinks below ground-level within an year after the completion of the work, the contractor has to refill it to ground-level at his own cost.

The soil for the work has to be taken from well defined borrow pits. If this is not possible, measurements may be made on sections. The slush removed from the well, should in no case be used for filling behind the lining.

Pulley fixing to old draw-wells.

In addition to the above methods of remodelling old wells, there sometimes arises a case, wherein old draw-wells

To face p. 280.

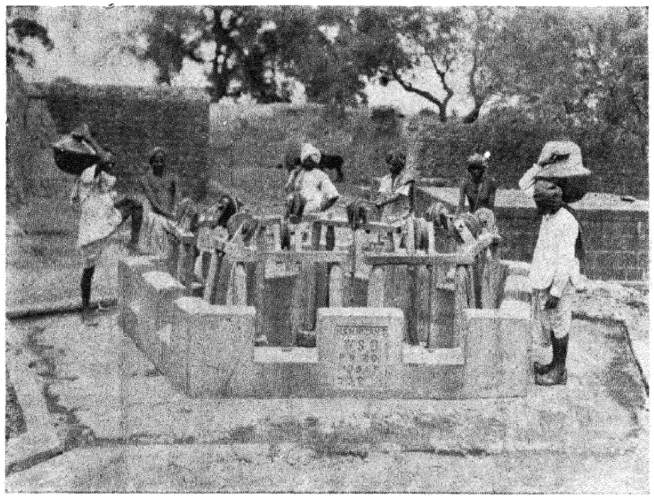


PHOTO PLATE NO. 18.—*An old well remodelled into a pentagonal well and provided with wooden pulleys.*

which have ample water with steining in good condition, requiring only pulley fixing, a parapet wall is built round the well and pulleys are fixed on them, when platform drain and cattle-troughs are also provided.

If pollution of the water is suspected, the water is emptied and the required quantity of lime is added as described below.

In such cases pointing to old steining is done to prevent accumulation of dirt and birds building nests therein.

Blocking Steps of Old Wells.

This is done in cases of all step-wells which serve as drinking-water sources. In cases where building of walls for blocking steps are not possible, the steps are dismantled and the ground below excavated vertically so that access into the well is effectively blocked.

Sterilisation of Old Wells.

It has been stated, after research by the Hyderabad Medical Department, that if the water in a well is raised to sufficient alkalinity as to turn red litmus into blue, that amount forms a lethal dose for guinea-worms. This allows the use of partially slaked lime and also limes of other strength. The subdivisional officers are supplied with a small booklet of red litmus paper to conduct the test, during sterilisation. The amount of lime needed is estimated at the rate of 5 grains to one pound of water, or 50 grains to one gallon of water (one gallon of water equals to 10 pounds). This works out to one pound of lime for 9 gallons of water (one pound = 450 grains).

Taking one cubic foot of average lime to weigh 55 pounds which will suffice for $55 \times 9 = 495$ or say 500 gallons of water or to express in other terms, the gallon of water divided by 500 would result in the number of cubic feet of lime required, to bring the water to sufficient alkalinity to form a lethal dose for guinea-worm carrying cyclops.

If potassium permanganate is to be used ($KMnO_4$) the following quantities are found sufficient.

½ Grain to 1 pound of water or,

5 Grains to 1 gallon of water or,

1 Pound for every 1,400 gallons of water.

After the work of sterilisation is carried out a "Panchnama" statement from the villagers including the patels is obtained, to confirm that the process was carried out effectively.

Filling up Old Step-wells.

Old wells which are not in any way useful to the villagers are filled up, provided the total cost does not exceed Rs. 50. To reduce the cost as much as possible it is found advantageous in some cases to fill up such wells a little above the mean water-level. The filling is done with any available material nearby.

Summer Water-level Survey.

In order to test the dependability of wells that are constructed (including remodelled ones, etc.) regular summer water-level surveys are conducted almost at the end of summer months when the water-level in wells will be at their lowest. Usually such surveys are conducted for 3 to 4 successive years to get an idea of the dependability of the wells. As an instance, the results of such a survey conducted in various districts during the last four years are tabulated below :—

Year	No. of wells surveyed	Average Depth		Average W.L. in the well	No. of Wells with less than 2′ of water	Percentage failure
		Of well from parapet	Of water in the well			
1938 ..	457	42′.18	14′.76	27′.42	7	1.53
1939 ..	679	43′.53	20′.48	23′.05	5	0.73
1940 ..	991	45′.71	21′.80	23′.91	2	0.20
1941 ..	425	45′ 14	20′.18	24′.96	5	1.17
1942 ..	1,618	46′.50	16′.64	29′.86	65	4.01

It may be observed from the above figures that the percentage of failures in 1942 was the highest which is entirely due to failure of rains not only in the year under reference but also poor rainfall in the previous years. Further it may be stated that these failures were noted for about a fortnight

just before the rains started ; otherwise the wells fully provided the needs of the villagers and their domestic cattle. Probably these results are the best that can be achieved under the most adverse condition of topography, rainfall and other conditions inherent in the famine zone area of the State.

Thus the enormous difficulties the villagers were put to during the summer months for even a potful of drinking-water due to drying up of old wells, have now been remedied and protected water-supply fully assured.

The first summer water-level survey conducted in Osmanabad District was in 1941, which showed an average depth of 19.43 feet of water ; not a single well constructed by this department has ever so far failed in its supply.

Deepening of Wells.

As already pointed out a watch is kept by the village authorities on all the wells excavated and remodelled by this department ; any failures or repairs to be conducted, are intimated to this department through the Revenue Authorities (Local Fund Branch) in charge of these completed wells.

Wells which require deepening—in consequence of the (1) lowering of water-table due to unusual drought, or (2) perhaps in some instances due to abstraction of ground-water by neighbouring wells or, (3) accumulation of silt and debris at the bottom—are conducted in either of the following ways.

I. If the lining is carried to the bottom it may need underpinning before excavation is started or is done by other methods already described, *e.g.*, " Reverse method of lining " and sinking or by reducing the diameter of the portion to be excavated and then lining it if need be.

II. In cases of firm clayey soil or other heavy ground, the original linings of the wells are not likely to sink due to the sides being securely held, but in cases of loose sand or running ground, if the original linings show a tendency to sink, the curb method of sinking is adopted.

The deepening of wells is also sometimes conducted to increase the yield of water in wells.

Considerations on the Deepening of Wells.

The deepening of wells is held in great apprehension that sometimes even the already available water in the well may

be lost. Provided the well has just touched the upper part of the saturated zone of groundwater, it is impossible for such a phenomenon to occur, and the deepening should certainly result in an increased yield. But in cases of perched water-table held up on a thin impervious sub-stratum, the piercing of this stratum into the underlying unsaturated bed below, may result in that water being drained to lower levels of the underlying bed. If the water yielding bed is underlaid by a thick impervious bed, further deepening into that stratum would not affect the supply, but would form additional storage for that water. In cases where the nature of the underlying rocks at the bottom of the well to be deepened, is not known it is best to sound the bottom by means of auger or drill holes before any real work is commenced.

Increasing the Yield of Wells.

In the foregoing paragraphs, it was pointed out that the deepening of wells would either result in increasing or reducing the yield or providing additional capacity for the storage of the water.

In some cases, drilling holes at the bottom of the wells has given better yields but unless the topography and the nature of the rocks below permit them, such a course can never be a success. In case of wells with weathered rocks above and fresh below, the yield may be improved by suitably increasing the diameter of the well ; by running in galleries, or auger holes at right angles to the slope of the ground which may usually be at right angles to the flow of groundwater. In cases where the recuperation of water is very slow, increase in diameter would not only increase the yield but also give additional storage capacity. The yield of wells may be increased in cases where water-bearing fissures or veins are located and excavation done in those directions.

As has already been pointed out the yield in wells may increase after two or three successive periods of rainfall when the rainwater collecting in these wells may saturate the unsaturated water bearing strata present in them, even beyond their cone of recuperation, making them perennial.

The Repairs and Cleaning of Wells.

Repairs to wells and the replacing of pulleys, etc., are from time to time conducted as per requisitions from the Revenue

(Local Fund) Authorities from the yearly maintenance grant.

In cases where the cement concrete lining has cracked for some reason or other, it is rectified by building a fresh inner lining to the original shape and size, as patching the cracks serves no purpose.

Cleaning the wells and removal of silt, if necessary are also done.

Before entering a well for inspection purposes, it must first be ascertained whether carbon-dioxide (CO_2) has accumulated in the well or not. This is found out by the behaviour of a lighted candle let down the well. If the presence of the gas is indicated by the flame of the candle being put out, then the well is rid of this gas by means of forced ventilation or by throwing limewater. The gas may be absorbed by lime water, but usually some method of stirring the air, by means of buckets of water thrown into the well or by lowering and raising bucket filled with glowing embers, or bundle of leafy branches grass, or loosely tied sacks, may be adopted. These would stir the air and create a forced draught which would dilute and eventually remove the accumulated gas.

Sub-surface Dams.

In cases of arid and semi-arid regions, where well sinking is not successful due to various causes, such as the water table lying deep below the surface, and where the rate of evaporation is high or where waters are highly mineralised or saline as in areas of Raichur district and parts of Gulbarga district or where funds do not admit of deep sinking or boring, the construction of sub-surface dams on nala or riverbeds may prove successful with wide application.

The sites are to be carefully chosen and the beds of nalas or rivers should be sandy, with preferably the sides and the bottom of more or less impervious nature. Such sub-surface dams have been constructed in Raichur district where salinity is a potent factor with success.

Construction of such walls or even low bunds at suitable sites in the vicinity of villages affected with salinity to check the flow and form deep bed of water-bearing sand against the walls or bunds, have therefore, been recommended. The water thus held back in the sand will further have ample opportunities of percolating into the underlying strata or rocks thus replenishing the groundwater, and the sand beds them-

selves in their turn being replenished by each freshet. Even in worst years of drought, there are always a few showers and those sand traps would store sufficient water to considerably replenish the local and underground supply in its close vicinity. Since they are situated in drainage channels, they collect water as soon as rains fall and in this way shorten the period of water scarcity.

Before the activities of the Well Sinking Department came into being, the villagers of Parsapur (Lat : 16°-4′-50″, Long : 76°-47′-25″ ; Manvi taluq) lying within saline zone, had to walk 2 miles to a bend in small nala where fresh water was found in hot weather beneath the sand bed. Nothing could be done at this point as the supply was insufficient and the rocks on either side of the nala were the red syenites which are inherently found to yield saline water. After about a mile on the downstream side of the nala, a natural sand trap was located, formed by a portion of the outcrop of a band of grey gneiss traversing obliquely across the stream which was equidistant from the village as the bend in the nala from which the villagers were originally taking water. A well was put down on the bank on the up-stream side of this natural sand trap and is yielding a good supply of fresh water to the delight of the villagers.

In highly saline areas therefore, this method appears to be the only means of providing pure fresh water to the villagers. The water impounded by such means is protected from evaporation losses which are usually great in countries of arid and semi-arid nature besides being free from contamination by animals or other organisms that live on or about the surface of ordinary reservoirs. In addition, such subsurface reservoirs do not get silted up as quickly as surface reservoirs though the sumps may require periodical cleaning.

Recharge Wells.

In places of water scarcity and in regions of low rainfall devoid of any forests or other natural growth, the groundwater may be supplemented by what are known as drainage channels either into wells or other excavations below impervious strata exposing permeable beds at moderately shallow depths. This supplementing of water from the surface would result in augmenting the groundwater storage. Similarly wells known as 'Recharge Wells' may be sunk on the flood plains, giving opportunities of surface waters to soak into the ground as groundwater. Waters entering such wells

should first be freed from suspended matter which can be done by causing them to flow slowly through channels of gentle gradient or through grass or some undergrowth or by reservoirs above by which most of the sediments may settle before those waters enter such recharge wells. These wells will require periodical cleaning from silt and debris accumulated in them.

These wells may not show any perceptible increase in yield in cases of perched water-table, whose water-yielding beds are not within the zones of these wells, but, improvement will certainly be observed in wells which tap the same stratum that is exposed in the recharge wells. The water that is directed into recharge wells will gradually soak into the porous beds and extend laterally on an impervious substratum in the direction of the slope of the surface and will be available in wells further down the slope, though the recharge wells may have grown dry. This is more or less similar to wells which, after 3 or 4 consecutive monsoons, give perennial yields.

PART VI

Chapter I

Tube-Wells

In cases where the groundwater is deep below the surface beyond 80 or 100 feet, the open method of sinking is too difficult to be adopted ; as such it is necessary to employ some other means by which the water could be made available at the surface. This is achieved by means of tube-wells equipped with either hand or machine-driven pumps to lift the water.

The inauguration of this scheme of tube-wells, particularly for irrigation purposes in several parts of India, has naturally resulted in similar enquiries in the Hyderabad State where over 90 per cent. of the population are dependent on agriculture. The works on tube-wells, conducted in the Punjab, United Provinces, Bombay Presidency, etc., were visited and their results studied in order to arrive at the conditions under which they were successful and to see if such potentialities are available in the Hyderabad State.

Before going into the subject it would be advisable to mention about the different types of drills that are employed with particular reference to the one that is commonly used on such work.

I. The Jet Process.—is one by which water is forced into a pipe through a jet at the end inside the casing and the materials drilled being brought to the surface by the water rising between the two pipes. This method is only useful in cases of soft or unconsolidated materials.

II. Hydraulic Rotary Process.—The beds are actually cut by rotation of drill itself using water for removing the muck.

III. Rotary Core Drilling.—The beds or rocks of whatever nature encountered are cut by rotating steel shoe, fitted to the cylinder of about 6 feet long. Shots are added from

time to time to serve as abrasives between the shoe and the rock.

Sometimes instead of the cutting shoe, the edges are set with bort diamonds which facilitates the cutting.

IV. Percussion Drilling.—This consists of chisel edges connected to iron rods which are raised and dropped alternately on the rock or surface to be bored. Usually a tripod or a derrick is employed to which a pulley is attached round which a hemp rope carrying the iron rods with chisel edges are attached to one end, the other end being connected to a revolving drum of a winch driven by steam, oil or other power or in some cases by hand. The rope is thus raised and allowed to fall quickly delivering a blow on the surface of the rock. The rod is now and then rotated slightly in order to break the rock on which it falls into fragments or puddled into mud for removal by augers, bailers, sandpumps or other devices designed for the purpose. To prevent caving of sides lengths of iron tubing for lining are inserted and driven down systematically as the work progresses.

Each method has its own individual advantages; the rotary drill gives better results in extremely hard rocks than the percussion drill. In cases of rocks too highly jointed, the loss of water will be too great, and the shots used as abrasives may also be lost; the percussion method of drilling would prove more useful and satisfactory in such cases. Hence the use of such machines depends upon the circumstances and the character of the rock encountered; in some cases the combined percussion and rotary drilling is adopted. The use of water in these machines is a great factor and in places where large quantities are not easily available the percussion drill stands in preference to the core drilling which require from 1,000 to 3,000 gallons of water per day for efficient running, whereas in the former case the quantity required would be as low as 150 to 200 gallons per day, if the sludge water is to be recovered from a settling tank, and about 300 gallons a day for boiler use.

Owing to great improvements recently in the quality and design of percussion drilling, excellent results could be obtained; even the crystalline or other hard rocks can be easily pierced by such modern drills.

The adoption of such methods depends mainly upon the geological conditions that are present in an area an outline of which has already been dealt with in detail.

Possibilities of Drilled Tube-wells in the State.

In gneissic area.

For an appreciation of the following descriptions, a reference is made to the outline of the geological formations of the State with particular details on the Dharwarian, Gneissic, Bhima and Deccan Trap rocks given on pages 38 to 88.

*" On account of the uncertainties of sub-surface conditions, drilled tube-well in a gneissic area is always a gamble, an element of luck playing a great part in the success or otherwise of a bore. This does not however mean that there is no possibility of locating good supply of water underground in a gneissic area. Often the reverse is the case. The Mysore Well Boring Department have given a number of wells in the gneissic country from time to time and claim that they have gone to depths of about 150 feet and the scheme has been a success. There are a number of bored tube wells around Hyderabad which are quite successful. As yet we possess no data which has to be gathered through experience and observation to enable us to say with any degree of certainty, as to how far the scheme will be successful in these districts of the State where the country rock consists of crystalline gneisses. But it seems very probable on account of the extensive jointing noted in the gneisses and the enormous decomposition they have undergone, that sub-surface water travels to great depths in the gneissic country and it would be possible to locate copious supplies at depths. It has only to be borne in mind that due to the irregularities of the topography and depths of weathering in a gneissic area we are dealing with conditions about which there is no certain knowledge.

Possibilities of drilled tube-wells in the Purana Group.

" In the case of Sedimentary Series, we are dealing with conditions which are uniform over a well-defined area and this enables us to locate the water-table and the water bearing strata in a given area ; thus the information can be utilised for the sinking of drilled wells. The sandstones, shales and limestones occur in some definite sequence and by an intimate geological examination of an area it would be possible to define the thickness of the respective beds. These sedimentary beds are for all intents and purposes, nearly horizontal and on this account

*Extracts from the report by Dr. C. Mahadevan, M.A., D.Sc. Assistant Superintendent, Geological Survey Department, Hyderabad-(Dn.)

structural complexities do not exist. The problem of locating the aquifers in the area resolves itself to the finding of the water-bearing strata. The junction planes of the limestones and shales often yield good water. The sandstones if they are not too compacted through pressure, act as excellent aquifers. If we locate the depth of these water-bearing layers from the surface, we would know exactly to what depth the bore will have to be made to be successful.

" The possibility of drilled tube-well in a sedimentary area has hardly, if ever, been investigated and there seems to be a most encouraging indication of bored tube-wells proving successful in these formations especially when it is remembered that they generally fringe the Krishna, the Tungabhadra and the Bhima basin and over and above the rainfall, the river water that percolates through the underground, must also be taken into consideration.

Drilled Tube-Wells. in Gondwana rocks

" Thanks to the activity of the mining companies and the prospectors for coal in Warangal and Asifabad districts, we are now in possession of some information as regards the nature of the rocks to a depth of a few hundred feet from the surface. A number of sandstone beds with limestones and shales comprise the Gondwana formations in the area and the sandstones are generally non-compact. They are capable of receiving and yielding large quantities of water. As some of the beds are of considerable dimensions, it may be expected that drilled tube wells will be very successful in the area. Several of the bores during prospecting for coal, are said to have yielded huge supplies of water. The Gondwana Formations however, constitute only a small part of the State and are practically confined to the Pranhita-Godavery valley in Asifabad district and a narrow belt in Warangal district.

Possibilities of Drilled Tube-Wells in Deccan Traps.

On account of the geological peculiarity, " the possibilities of drilled tube-wells proving a success in the Deccan Trap area are immense. There would generally have to be no wild endeavour, as the sub-surface conditions are fairly clearly known and deviations would be exceptions. About 32,000 square miles of the State are covered by the Deccan Traps and comprise the Marathwara districts of the Dominions. There has been some sort of activity on the part of the Boring section of the Industries Department to provide drilled wells in this area. If their efforts have not been successful as one would desire to make

them more popular, it is because there has been a lack of precision of the geological conditions, a knowledge of which application could have helped to bore to the required depths for the well to derive the maximum benefit of the aquifers. The failures are generally due to the fact that either the bore stops in hard strata which does not contain much water or that it did not take the full advantage of the depth of the aquifer. With a thorough understanding of the geology of the area and preliminary spade work, it should be very easy to inaugurate the scheme of drilled tube-wells for irrigation in Marathwara. If a number of aquifers are pierced through and arrangements made during the course of the lining of the bores, to tap all the aquifers through perforations from the lining tube, it should be easy to get adequate supplies of water for irrigation purposes. The possibilities here are immense and have not been approached scientifically at all. A large number of successful tube wells suitably distributed, will revolutionise agricultural prospects and instead of waiting for the vagaries of weather cultivation would come under control of the agriculturist.

" For vast irrigation projects, it is necessary to have requisite geological conditions, a great outlay of capital and a stupendous organisation. While not losing sight of the necessity of such schemes, it would be worth investigating the possibility of inaugurating a general scheme of drilled tube-wells for irrigation purposes, to improve the condition of the agriculturist and to get within his means a device so necessary for his well being ."

In broad basins with talus and with gently sloping highlands all round and with aquifers (porous rocks) of considerable thickness interbedded in these rocks, it would be possible to get huge supplies as in cases of Yedrami and Diksal villages for irrigation purposes. The possibilities of putting tube-wells in Deccan Traps appear to be immense, if scientifically approached. A large number of such wells spaced at suitable intervals and located at favourable spots may perhaps revolutionise agricultural prospects which are now controlled by the vagaries of the weather.

Some of the advantages of the tube-wells may here be enumerated.

I. The water is almost invariably free from bacterial contamination.

II. The tube-well scheme proves less in capital outlay than a major irrigation system; it can be gradually developed as the demand for irrigation is established, enabling a return on the capital on a commercial basis from the second or third year of operation as against the 12 to 15 year period for major projects.

Advantages of Tube-wells.

III. It is flexible in its application. A tube-well can be sited at points of intensive cultivation, and omitted at any rate in the first instance in the less cultivable tracts. A canal system on the other hand, must traverse the whole region from the hill to the last field irrigated, regardless of the unsuitability of portions of intervening tracts.

IV. It lends itself readily to the system of volumetric or quantitative scale of water, a principle which is the ideal objective of irrigation engineers, and was recommended by the Royal Commission on Agriculture in 1923 who observed that there was a wastage of 30 to 50 per cent. of the water supplied in the case of wheat, to the detriment of both the soil and the crop.

Even if the Government do not derive much revenue from the cultivators in the arid regions, the indirect benefits conferred by the scheme would be innumerable. It ensures against famine which results in the frequent remissions of revenue and distribution of Taccavi. Apart from the loss of revenue sustained by the Government in the form of remissions, the other serious indirect problems that confront both the Government and the people are the deterioration and the depletion of cattle due to lack of fodder, the increase in crime incidence, and the migration of labour to industrial areas outside the State. Any measure which would alleviate the chronic visitation of famine deserves a careful examination. Though the initial outlay may not promise a direct return to the State the beneficial effects attained indirectly would constitute a potential advantage to the Government.

Rural Water-supply by Tube-Wells in Hyderabad State.

The substitution of tube-wells for open wells as is being done in Bellary and some other Provinces in India was considered for rural water-supply but after taking the various aspects of the question into account it was decided that open draw-wells are most suitable while tube wells may be advantageous for individual or private houses. There are some inherent handicaps in the provision of tube-wells fitted with

hand or power-pumps for village water-supply due to rough and indifferent handling of them, and the frequent breakdowns involving the employment of mechanics and the stocking of spare parts. A tube-well with a discharge of about 200 to 300 gallons per hour does not fulfil the requirements of the villagers.

The absence of the requisite geological and other attendant conditions, except at few places, does not warrant the provision of tube-wells for village water-supply. Some promising areas in the State have first to be scientifically investigated, before embarking on a comprehensive tube-well scheme. Other sites where tube-wells may be driven with success are as follows :—

1. Deltas of large rivers (Indo-Gangetic plains).
2. River valleys, stream beds, ancient or modern water courses.
3. Plains in which rivers meander ; lake plains.
4. Beaches and dune country.

Before concluding the subject it is relevant to quote the views of late Captain L. Munn on Tube-Well Scheme for rural water-supply, given on page 5 of the Annual Report for the year 1340 Fasli (1931.)

"I understand that the Famine Board have been recommended to change to tube-wells in preference to wells of our present design.

"First of all, save in places in the sandy bed of the Maski nala, I know of no site where the Geology would allow tube-wells to be driven. If by 'Tube-wells' bore-holes fitted with pumps is intended, I have already shown by comparing our figures with those of a Southern Indian State, that not only are my designs of wells cheaper than the actual bore-holes, the water-supply more adequate but further that my design of well has the advantage of allowing many hundreds of villagers to draw water by hand, whereas, if bore-holes were introduced, each bore-hole to give sufficient water for village supply, would have to be fitted with a deep well power pump and cistern costing several thousand rupees.

"A further objection to the scheme, would be that each bore-hole and pump would require a trained fitter to daily attend to the machinery.

"In gneissic formation the chance of striking a big cleavage by a bore-hole carrying sufficient water for village

supply is problematical, the odds being very much against you, though bore-holes will generally give sufficient supply for a house, and for that purpose fitted with a 1-inch hand pump is to be recommended. But for village supply from practical considerations to supply 1,000 of population, you would require 20 bore-holes and such pumps, which would only give 300 gallons per hour. So the scheme is impracticable.

"Even if the drilling of bore-holes would solve the question of touching water, uncontaminated with objectionable nitrates and nitrites, etc., there might be some argument in their favour, but even this hope must be discarded, as the water is all derived from the same source, viz., the rain, and we have found by experience that even water at 62 feet, was contaminated with chemicals, though we do not know if bacteria was present."

The late Captain L. Munn has many a time proved to the Government by comparing his figures with those of the Mysore State tube-wells that not only is his design of wells cheaper (design having been further improved and cost still reduced subsequently) than bore-holes and water-supply more adequate.

Save for oiling the pulleys by the villagers and other petty repairs, open wells need no supervision, whereas in case of bore-hole pumps special mechanical staff have got to be maintained for constant supervision and repairs. Even after maintaining the mechanical staff, it would be essential to provide two tube wells for the general public and two for the Harijans, so that in case of either of the wells getting out of order, they could take advantage of the other ; else they will have to resort to old open wells which, due to long disuse, must have been polluted with the result that they will become victims to water-borne diseases which would bring them back to their original unprotected state of water-supply, even after spending huge amounts by the provision of tube-wells to villages. It is therefore definitely concluded that for rural water-supply, protected open well system is the most suitable than bore-wells.

PART VII

CHAPTER I

Miscellaneous

Attached to the department is a workshop which, starting with a smithy branch, gradually developed into a Manufactory where pulleys, panel reinforcement, steel plates of moulds for cement concrete lining, iron steps, all spare parts for engine and pumps etc., are now manufactured at comparatively cheaper rates than outside firms. A list of parts of various engines—Lister Deutz, Ford and Hamsworthy—manufactured in the workshop, compared with their costs of the outside firms are shown below :—

Work-Shop.

Lister Petrol Paraffin Engine. 3B.H.P. Type 13 F. K. direct coupled to L.E. 1½" E.D. centrifugal pump.

Serial No.	Name of parts	Cost					
		Firm			Workshop		
		Rs.			Rs.		
1	Pulsometer bed plate	8	0	0	7	6	0
2	Magneto brackets	3	12	0	3	7	0
3	B.C.S. spindle with nose caps complete	35	0	0	14	0	0
4	Big end bush	5	5	0	3	8	0
5	Small end bush	3	2	0	2	13	0
6	Starting handle bracket	4	4	0	4	3	6
7	Oil feeder with stud and wing nut	6	0	0	5	4	0
8	Exhaust manifold	31	9	0	16	8	0
9	Governer Bush	4	0	0	2	3	0
10	Coupling Disc	2	8	0	1	8	0
11	Valve rocker	7	0	0	4	2	0
12	G. M. Neck bush	16	12	0	5	0	0
13	Brass air thumb screw	1	4	0	0	11	0
14	Brass cock & plug for priming cup	12	2	0	6	11	0
15	Magneto coupling	2	9	0	2	2	0
16	Brass fuel cock	5	0	0	4	0	0
17	Coupling leather washer	5	0	0	3	13	0
18	C. I. coupling for impeller shaft	15	0	0	9	9	0

Serial No.	Name of parts	Cost: Firm			Cost: Workshop		
19	Priming cup	7	0	0	2	12	0
20	C.I. gland	6	12	0	4	0	0
21	Brass grease cup lid	1	8	0	1	4	0
22	Exhaust silencer	5	0	0	3	0	0
23	Water jacket cover	4	10	6	3	11	0
24	Valve rocker shaft	2	8	0	2	0	0
25	C.I. ball-bearing housing	22	8	0	22	6	0
26	Fuel tank	8	4	0	8	0	0
27	Aluminium carburetter (complete) ..	54	0	0	33	9	0
28	Connection pipe nut & nipple ..	2	8	0	1	10	9
29	Fuel tank bracket	2	6	0	1	7	0
30	C.I. ball-bearing housing and cover ..		..		22	6	3

Deutz Kerosene Engine, 3–5 H.P. type M.A. 608 horizontal single cylinder. 4 stroke—direct coupled to Amaj Hilpert Centrifugal Pump

1	Exhaust silencer	5	0	0	4	4	0
2	G.M. gland bush	16	12	0	6	0	0
3	Brass can bush	8	0	0	4	10	0
4	Grease cup cock	2	8	0	1	13	0
5	Governer spindle		..		4	0	0

Ford Petrol Paraffin Engine, H.P. 20-32, Hylander Model "A" direct coupled to L.E. 3" E.D. centrifugal pumps.

1	Three way cock	8	0	0	5	2	0
2	C.I. starting handle pulley	7	0	0	6	0	0
3	Brass band for fuel connection ..	2	0	0	1	8	0
4	Brass cup for fuel tank	2	8	0	2	0	0
5	Aluminium end cover for ball bearing housing with screws	10	0	0	8	4	6
6	Valve guides		..		1	8	0
7	Brass screw nipple	2	9	6	1	0	0

4 H.P. Hamsworthy Engine, Petrol Paraffin gear coupled to 2½" centrifugal pump.

Serial No.	Name of parts	Cost					
		Firm			Workshop		
1	C.I. jet body	16	10	9	11	2	0
2	Big end bush	10	8	0	5	9	0
3	Right hand cover	19	0	0	14	7	0
4	Left hand cover	35	0	0	12	4	0
5	C.I. slip ring	15	0	0	4	0	0
6	Brass slipper	8	0	0	3	14	0
7	Crank washer	10	8	0	5	14	6
8	Fuel pump plunger	4	0	0	2	3	0
9	Cylinder head cover	3	0	0	2	15	6
10	Governer balance block	8	12	0	2	13	0
11	Rocker arm	11	6	0	4	0	0
12	C.I. petrol tank..	27	0	0	19	0	0
13	Piston with rings complete (oversize) ..		..		20	0	0
14	W.M. lined bearing	21	1	0	8	9	6

Miscellaneous.

15	Pulley with bracket and spindle complete	15	8	0	12	8	0

It may be seen from the above, that the advantages of owning a workshop are great besides manufacturing articles at cheaper rates, it can supply them immediately as the demand arises.

The workshop is also able to provide work to some of the local unskilled men thus providing them opportunities of training them into skilled artisans, who will be in a position to get employed elsewhere on such works to their advantage. In addition, if time permits spare parts or other materials to meet local demands are also manufactured in the workshop. By this means the workshop is now not only able to maintain itself, but is also in a position to get an income to the Govern-

ment. The equipments in the workshop are :—

1.	Lathe Machines	2
2.	Drilling Machine	1
3.	High speed grinder	1
4.	Blower	1
5.	Oxy-Acetylene Welding Plant	1
6.	Buma cylinder boring machine	1
7.	Lister engine (Diesel)..	1
8.	Hack-saw machine	1
9.	Honing Machine	1
10.	Keplo	1
11.	Moulding Shop	
12.	Smithy Shop	
13.	Carpentry Shop	

During the year 1942., three hundred machine parts were manufactured.

In cases of manufacture of articles in workshops the following procedure is adopted.

I. No item is taken for manufacture in the workshop unless there is a written order from the Special Officer.

II. The workshops when applying for orders for the manufacture of any articles, should submit, in addition, a certificate from the stores that materials needed for the manufacture of such articles, are either out of stock or are to be ordered to bring up the stock to the maximum limit for future use.

The workshop will also submit an estimate (in triplicate) for the articles that are to be manufactured but in cases where estimates have already been sanctioned by the Special Officer, reference should only be quoted. A copy of the sanctioned estimate (of the triplicate sent) will be returned to the workshop, duplicate to stores, and the third retained in the office for record.

III. After orders have been passed by the Special Officer, the stores will issue a work order to the workshop to carry out the job, along with the work order register for noting the job number on the sanctioned estimate.

IV. While indenting materials for the job, the workshop will note the job number in the indent, to enable the stores to issue materials to the extent sanctioned in the estimate.

V. The stores will note in P. W. D. or W. S. D. Form Number 10., the authority for executing each job.

Chapter II.

Measurement Books.

The attention of the Executive Staff who record the measurements is drawn to the following points, besides the usual printed instructions contained in the Measurement books.

1. An up to date index is to be posted.

2. Reference to the previous measurements should be quoted in the Measurement book. " Previous measurements " here mean all the previous measurements taken from the commencement of the work.

3. A clear sketch showing the sizes of wells at different depths and the classification of soils, are to be given at the commencement of every measurement.

4. Reference to all Inspection Notes of the sub-divisional officer and Special Officer concerning the wells should be quoted with their dates.

5. The following informations about the well should be recorded.

i. Total depth of well from ground-level in case of final bills.

ii. Total depth of well from top of parapet in case of final bills.

iii. Water-level from top of parapet in case of final bills.

iv. Water-level from ground-level in case of final bills.

v. Size of well whether 4′ hexagonal, 4′ pentagonal, etc.

vi. Original depth of well from ground level in case of first and final bills of old wells.

vii. Original size of well in cases of old wells.

viii. Original water-level in case of first bill of an old well.

ix. Height of cement concrete lining in case of final bills.

x. Number and type of pulleys in case of final bills.

xi. Final serial number on the number plate, in case of final bills.

xii. Type of platform, single, double, full or any other type in case of final bills.

xiii. Size of cattle-trough in case of final bills.

xiv. Taste of water, whether sweet or brackish in the first bill recorded after meeting with water and in the final bills.

xv.. Reference to the authority for sanction of estimate with sanctioned amount, in case of first and final bills of old wells.

xvi. Reference to the authority for widening the well beyond standard diameter in case of wells where this work has been done.

xvii. Reference to the authority for starting the lining.

xviii. The complete labour payment finally made by the contractor is to be certified in the measurement book in case of final bills and if necessary in the intermediate bills also. If any payment is due by the contractor, such amount due is to be ascertained with the help of Patels and Patwaris of the village and intimated to the office of the Special Officer for recovery from the contractors bill for payment to labour through the sub-divisional officer concerned. It is advisable if the contractor is also present at the time of this payment.

xix. The charge sheet signed by the Patel and Patwari and the officer who hands over the well to the former is to accompany the final bills.

xx. Receipt for anna 0-1-0 paid by the contractor to the Patels for oiling the pulleys should also accompany the final bills.

xxi. This is to be certified in the final bills that final cleaning of the well is properly done.

xxii. Signature of the contractor in token of his acceptance of the measurements, the sectional officer for having recorded the correct measurements, and the sub-divisional officer for checking or approving the work are to be made in all the bills. The final bills are to be invariably checked by the sub-divisional officer who will make the endorsement " Checked work " in the measurement book.

xxiii. The number of piece contract certificate is to be given at the commencement of every bill. In case of final bills it is written " Piece contract certificate (P.C.C.) number :— and Final. "

xxiv. Reference to the authority for removing the silt fallen from the top into the well is to be quoted if any.

xxv. In case of abandoned wells, reference to the orders for abandoning the well is to be quoted.

xxvi. Reference to the authority for carrying out any work which is against the standard design or of special nature is invariably to be quoted.

VI. The date of recording the measurements is to be the same as the date of initials of the sectional officer as it is expected that the measurements are entered in original in the measurement book on the work-spot when the work is actually measured. The data should also tally with that given in the diary of the sectional officer for the corresponding period.

VII. The minimum amount of each bill will be Rs. 100, with the exception of some of the contractors, whose financial position does not allow them to abide by this rule. In case of these contractors, the minimum will be Rs. 50, should they request for bills being prepared for that amount. Previous permission will have to be obtained to class any contractor under any of the above two divisions.

VIII. At the end of every bill and before the next bill is commenced, space has to be left for affixing the " Pay Order."

IX. Separate measurement book is to be used for different blocks, different contractors and for new and old wells.

Allocation of Stock Articles in the Measurement Book.

The stock articles supplied by the Government, such as cement, pulleys, number plates, reinforcement, etc., are indented by the sectional officer who is responsible to see that the articles are indented in time and that the works are not pending for want of them in any way. The allocation of these articles to be charged on to the different works has to be shown in the measurement book simultaneously as the work is done and paid for, and not delayed till the final bill. In the final bill, the up-to-date and detailed allocations are to be given and the quantity already allocated is deducted from it.

The contractors, after using the government cement should not return the empty bags but use them for curing

the cement concrete lining, and if found in surplus they can use them or dispose of them as they please. The department will however recover the cost of these empty bags at one anna per each bag. The sectional officer while allocating the cement in the measurement book should mention the number of bags for which cost has to be recovered from the contractors.

Inferior Quality of Work.

The sub-divisional or sectional officer should see that no inferior quality of work is done or allow such work to be completed. If any inferior work is found to have been done in his absence or against his orders the sectional officer will at once report the matter to the sub-divisional officer who will inspect the work and, if found as reported, get it dismantled at once in his presence and get it reconstructed at contractor's expense.

[*Statement,*

Progress Report.

20* The monthly statement of works in progress in each taluq is to be submitted by the sub-divisional officers within the first week of the following month in the form given below :—

Block number	Contractor	Total No. of Wells		State of Progress				Total of column 6 & 8	To be started		Total of columns 5, 9, 10 & 11	Remarks
		Original proposals	Revised proposals	Completed wells	Under sinking	Under lining	Nearing completion		New and remodelled	Step blocked, sterilised & filled up		
1	2	3	4	5	6	7	8	9	10	11	12	13

Chapter III.

Returns of Stock and Tools and Plant.

These are submitted every month. The accounts of the month are closed on the 25th of each month, and P.W.D. Form No. 12 submitted in duplicate to reach the Special Officer by the end of the month. The head store-keeper will return the duplicate copy by the 10th of every month through the Special Officer. He will admit only such issues for which allocation statements ending 25th of each month have been sent to him by the Special Officer. The stores will not accept any allocations directly from the executive staff.

It sometimes so happens that in Form No. 12 the balance shown by the sectional officers do not tally with the corrections made by the stores and they are unable to verify the differences. In order to overcome this difficulty, the Form No. 12 is modified as shown below with which two statements in Form No. 9 one for receipts and the other for issues are sent. Reference to indent for receipts and head stores for issues have to be quoted to facilitate reference.

escription	Unit	Balance remaining in stores as per last month's return			Receipts during the month as per statement enclosed	Total	Issues during the month as per statement enclosed	Balance running in store at the end of this month	Remarks
		As per S.O.'s returns	Allocated by sectional officer but not adjusted by stores, vide form No. 9 of previous month	Total as per stores correction					
1	2	3	4	5	6	7	8	9	10

The stores will return to the party concerned Form No. 9 of receipt and issues with the duplicate verified copy of Form No. 12. During verification, the stores will make in Form No. 9, of issues any of the following remarks as the case may be.

(*a*) Adjusted as per allocation statement received from the office of the Special Officer.

(*b*) Allocation statement not received from office of the Special Officer.

(*c*) Allocation statement received from the office of the Special Officer but ....(reasons given by stores) will be adjusted in the next month's account.

On receipt of Form No. 9 of issues, the sectional officer will be in a position to verify the balances shown against him by the stores.

Items not adjusted in previous months will be repeated in Form No. 9 of the subsequent month, till adjustment is made, but reference to the month from which item is remaining unadjusted is to be quoted.

At the time of handing over and taking over charge, the receipt of contractors for materials issued on works in progress is handed over by the relieved officer to his reliever, who will consider these materials in his charge and inform stores accordingly to allocate, in due course, these materials against his loan account, the idea being that the relieved officials loan account of stock articles is to be finally closed when he is relieved from a particular section.

In some cases disputes have arisen between the executive staff and the contractors, on the sectional officer stating that the materials while in custody of the contractor have been found missing or short and the contractor denying the outstandings. Both the parties have thus no proofs to their statements. In order to overcome the confusion, it is ordered that each loan holder shall maintain a separate ledger for each contractor, in which separate pages are allotted for each material. Signature of contractor or his maistry (a written authority by the contractor being necessary for the latter) is obtained for each issue and allocation which is also attested by the loan holder. The contractors if they so desire, can maintain a duplicate copy of the register for their informa-

tion in which the loan holder will likewise attest the transactions. The form of maintaining this account is given below :—

Previous No. in the custody of contractor	Issue			Total No.	Signature	
	Date	No.	Name of work		Contractor	Sectional officer
1	2	3	4	5	6	7

For articles in the custody of the contractor he will alone be responsible.

APPENDIX I.

An Aspect of Rural Uplift

BABUL TREE

The means of solving the fuel problem for rural areas and consequent conservation of valuable manure.
An aim at reforestation

An Aspect of Rural Uplift.

BABUL TREE.

The Means of Solving the Fuel Problem for Rural Areas, and consequent Conservation of valuable Manure.
An Aim at Reforestation.

As Special Officer, Well Sinking Department, I had to tour into villages of the State getting into remotest parts, on the work of providing protected and clean drinking water supply for the Rural Areas. Prompted by a natural curiosity to utilise this opportunity—which may not repeat itself—to other useful purposes of village uplift, etc., a study of the general conditions and the modes and customs of the villagers was done, which would have involved great additional expense to the Government.

The fact that lot of cattle dung distributed round the villages on the fields, by the natural process of cattle grazing, are either being deliberately removed for immediate use as fuel, or stored near houses for similar use later on, was brought home to my mind, time in and out, which might have been better utilised for the enrichment of soil fertility. In this connection the United Province Five-year Fodder Plan* which aims at the following improvements, may be mentioned. " The Committee is to examine research projects and institute fodder and grazing experiments ; try to increase firewood and so do away with the use of cowdung as fuel ; develop fodder production from the eroding ravine lands of the Gangetic Plain : and extend the system of growing fodder trees under *Taungya* cultivation, already so successful in the poorer forest types in Sharanpur and Dhera Dun.

" In the U.P. the fodder requirements amount to 130,000 tons a day ; the weight of cowdung burnt yearly is far in excess of the total weight of timber and firewood extracted from Government forests ; and there are some 15,000 sq. miles of uncultivated waste, much of which with proper management could produce more fodder and fuel than it does now ; so there is plenty of work to be done. "

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*Soil erosion in India by R. Maclagan Gorrie, published in the *Illustrated Weekly of India,* November 10, 1940.

The cowdung though possessing very great advantages as fuel by its property of quick firing and slow smouldering combustion remaining as cinders for a pretty long time yielding relatively a good heating capacity yet its use as such is very much to be deplored considering the huge amount of this material that is being annually wasted and which may otherwise be used for the pressing need of soil nourishment. The imperative need for the villager to conserve the dung as manure can fully be appreciated when it is realised that he is too poor to buy artificial manures. The practice of using dung as fuel does not appear to be due to any lack of other fuel in the vicinity, but to the ease with which it can be obtained and handled. In this connection the views of Mr. F. L. Brayne * may be quoted. "The use of cowdung as fuel is not always due to the fact that no other fuel is available. It is often just thoughtlessness or prejudice." Considering that the main bulk of the people in the villages are agriculturists and in order to suggest ways and means of how they could improve the soil, by the only available natural manure—a greater portion of which is now being otherwise wasted—I began to ask myself, as to how best this evil, though popular practice could be effectively put a stop to, and to evolve an alternative scheme by which this loss may be easily and effectively replaced. The suggestion put forth before the Royal Agricultural Commission of 1926, that the waste areas near the villages should be planted with fuel trees and that fuel resources should be established as near the villages as possible was also considered ; but the impracticability of the scheme forced itself into my mind, considering the want of any waste land near the villages and specially because of the variation in the soil and sub-soil, which may not prove suitable to the growth of the types of fuel trees that may be recommended. A simple, but at the same time an effective method had to be evolved, involving only the minimum expenditure and propaganda in the growth of a fuel tree, which must combine all the advantages of adaptability, commercial value and above all its usefulness to the villager in particular.

Babul Tree most adaptable and best fitted.

I do not claim to be an Arboriculturist or a Botanist but still from vast experiences and close observations on my tours in the districts of Raichur, Gulbarga, Osmanabad and Bhir, I was able to notice that the Babul Tree (Bot : Acacia

*Indian Economics by G. B. Jathar, M.A. & S. G. Beri, M.A., Vol. I, Third Edition, 1931 page 242 (see Brayne, Agricultural Commission Report, page 4).

Arabica) answers all the needs and purposes in preference to any other tree or trees. The very nature of the tree suggests, that it has very well adapted itself to the conditions prevailing in arid regions and to the widely varying conditions of soil and sub-soil and the nature of water that is available in them. It is a common sight to see in the Deccan, a monotonous, dry, dreary and treeless landscape which is only broken up by the presence of Babul Trees. The adaptability of this tree is so surprising, that it has been found to grow in its normal form even in saline areas, which are so common a feature in Raichur and parts of Gulbarga districts.

How trees take in minerals from water, and how the nature of sub-soil and groundwater influence their growth.

All the trees derive their minerals from the water available in the soil and sub-soil and in some cases from underground sources, which is abstracted into their system through root-hairs. The culture experiments for the growth of plants carried out in the laboratories show that the necessary minerals needed for a plant, could only be administered through water in very dilute solutions, which standard sometimes falls below the standard of the so-called local potable waters in an area. If the solution of water by any means exceeds the optimum that is needed for a plant life, then the plant in striving to adapt itself to the new condition imposed, may either try to struggle and live on for some time or may eventually perish in the attempt. The root-hairs being solely responsible for the absorption of water from the ground into the plant, have to maintain a stronger solution of mineral water at their tips, than the one in the ground, so as to keep on the process of '*Osmosis*.' Hence there is every reason to find great disparity in the natural growth of trees from place to place. Incidentally it may be remarked that Ficus Religiosa tree in the majority of cases is found to grow on or in the near vicinity of sweet water sources in the ground and has been found to be conspicuously absent in or near saline areas or areas of brackish water supply. Tamarind (Bot: Tamarindus Indica) tree, likewise appears to respond similarly, and it may therefore be pronounced that the growth and presence of certain species of trees in a particular area, is also an indirect evidence of the nature of water available in the ground.

Other important factors that are to be considered in this connection, are the nature of soil and sub-soil and as well as the rocks underlying them, the climatic condition, the amount of rainfall and altitude, etc. The nature of soil and sub-soil

To face p. 313.

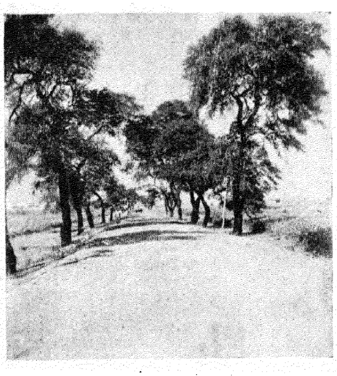

PHOTO PLATE NO. 19.—*The growth of Babul on either sides of the trunk road, adds beauty, gives shade, and above all yields timber for various useful purposes, besides serving as an important fuel to the villagers.*

is also indirectly reflected in the nature of the water that is available in them in the area and this has been dealt with in detail in the foregoing paragraphs. Without going further into the details of these other subjects and limiting myself to the scope of this paper, in the choice of Babul, by proving its wonderful adaptability in the scheme of the growth of fuel tree, it becomes necessary to deal with the tree itself, as regards its availability, cultivation, commercial value and its usefulness.

Even as things stand at present the tree is easily available and I cannot think of any village where it cannot be had either in or somewhere near its vicinity.

The process of cultivation is neither costly nor does it involve the use of skilled labour. It is a hardy fairly quick growing tree and does not require water or constant supervision. It is therefore proposed that waste lands if any near the villages ; the sides of country tracks and sometimes even trunk roads and particularly the waste lands on either sides of the nala banks where the water-table is high and the soil moist, are recommended to be claimed for the plantation of this tree.

The dry seeds (pods) should be collected in summer. As the field lands in most cases abut either the cart-tracks or nala banks it would be easier to plough such lands which are acquired, when the ploughing of the fields themselves are undertaken, as this procedure would dispense with any extra labour or cost. After thus preparing the land the fresh collected seeds should be simultaneously sown with the sowing of the fields. Perhaps the first sowing of these seeds may be considered to be a heavy duty but when once this is done one can entirely forget all about it for the seemingly great work has not only been started but set in motion for ever. The springing sprouts which are crowded at first may then be regulated to form into definite rows of 10 feet apart with the same distance from tree to tree by pulling out the superfluous ones. As the trees before their maturity would have shed their seeds many a time on the ground for other sprouts to spring up and which may be regulated in the manner already described, thus keeping on the process of growth continuous.

The seeds sown in this manner would take about 25 to 35 days the maximum to germinate. But if the germination is to be accelerated the seeds may then be treated in either of the following ways :—(*a*) The seeds may be immersed in

water and its temperature raised and maintained at a steady heat of 50 degrees centigrade for a period of about an hour when they may be removed from the water and dried. (*b*) Another easier method which is already known to the villagers and which they can easily follow and carry out in preference to the first method which requires some manipulation and which the villagers may not have the patience to conduct is to soak the seeds in cattle urine for a period of twenty-four hours and then sown at the proper season to germinate. These methods would soften the outer hard integuments which are then easily broken open by the germinating seeds. When once the seeds germinate they would sprout out as saplings and would gradually adapt themselves to the environment during the monsoonic season. After thus establishing themselves firmly in the ground they may tide over the ensuing summer and would then gradually grow into a full blown tree. About 10 to 20 years or taking the average between the two extreme limits it would roughly take 15 years for the tree to reach maturity to yield marketable timber. But before the trees reach this stage and in order to govern their growth and bring them up to a symmetrical form they may have to be pruned occasionally.

Pruning of trees.

The pruning should be carried out at the end of cold weather as the wounds caused would not only give the least pang for the trees but would heal up at the shortest possible time. Pruning is an art and it has to be conducted in the best manner possible. The 'hacking' or 'mangling' method of pruning as is done by the use of axe usually by the thoughtless and ignorant villagers should never be adopted or encouraged as the tree is an active living being endowed with powers of feeling, etc. The necessary implements for the use of pruning are the saw, a sharp knife, a cutting pliers or a pair of shears.

The unnecessary branches should first be cut off with the sharp knife flush with the stem when the wound will soon heal up and the place gradually gets covered with bark.

Small branches or twigs may be cut off advantageously at the forked ends flush at one quick cut the flush face obtained being so manipulated as to be either vertical or slanting downwards, the latter method being more preferable. In removing the thicker and woody branches the bark round the branch should first be cut off with the sharp knife at the place and the underside sawed first for a little depth and finally from the upper side to go through the undercut already

made so as to expose an even surface. If by chance, any jagged ends are left at the cut portion, they should be pared smooth with the knife and the cut then be coated with cow-dung. Such branches should be cut off above a foot or so from the trunk of the tree. The cut surface should preferably present a face in position already mentioned.

While the trees are still young, their terminal buds of the lateral shoots should be pinched off and so also the lowest lateral branches, so that they may develop in girths with straight stems. The pruning should be done in stages every year and not more than two rows or tiers should be removed in each season. The regulation should be carefully observed, as otherwise not only the growing of the tree is highly affected, but would make it top heavy thereby making it put on a hunch-back.

The utility and the benefits that accrue by the growth of these trees as advised are two-fold, which on the one hand will improve the economic conditions of the villagers and on the other hand would provide a source of additional income to the Government.

The tree is useful in so many ways, chief amongst which are :

Uses.

1. At the very outset, the superfluous plants which are pulled off in regulating the first crowded growth, would form into such quantities as to be useful—after drying—for fuel. The constant pruning, and other useless portions of the trees would from time to time yield fuel to the villagers. Finally when the trees reach maturity—after the lapse of 15 years—they would maintain an uninterrupted flow of fuel, entirely replacing the use of cowdung which may be used in the vital problem of soil nourishment.

2. The trees being highly woody, lends itself for use in a number of ways. Most of the villagers being agriculturists are constantly in need of agricultural implements and this tree by its property above described and in view of its great relative strength, durability and low cost, is much priced in preference to others, in the manufacture of these implements which have to stand rough handling and great strain. In some cases, if the girth of the stem can permit, cart wheels are also made out of it, as it is able to withstand variations of heat, cold and dampness without any visible deteriorating effects. The insects which are commonly found boring into

bamboos and other wood, reducing them within a short time into mere pulp, seem to have very little or no influence over this wood, and this feature serves as a great advantage to the poor villager in dispensing with the use of wood preservative which he cannot afford to buy. The greatest and at the same time the most commendable purpose to which this wood is put into use, is in the manufacture of cart axles, as its iron counterparts are very costly and not within the easy reach of the villager or within the moulding capacity of the village blacksmiths, who in some villages are entirely wanting or non-existent. These features, have very important bearing on the life of the villagers, as in spite of so much advancement and industrialisation there are many parts still in India wherein cheap and at the same time common articles of utility have failed to reach, for want of cheap and easy communications by roads or railways which form the main links between various places.

If stems of sufficient sizes are available, they can be made into timber and utilised for building constructions.

3. The leaves of the trees as well as the seed pods are much relished by sheep and goats, which form one of the mainstay in the life of human beings, as they supply not only the much relished meat, but also wool for covering and skin for equally other useful purposes. The pods are used as fodder for cattle.

4. The thorny twigs can be used for fencing the fields from maurading animals or persons. This practice though it may appear trifling at first is most significant again in the life of the villagers, as their crops have got to be protected. No other efficient and cheap device of fencing can be entertained or undertaken in preference to this method in vogue.

5. The dry wood put to the process of destructive distillation besides yielding other useful distillates, will leave behind pure carbon in the form of charcoal, which may be utilised to advantage for domestic as well as commercial purposes. The innovation of the *Producer Gas Plant* for mechanical propulsion and for various other purposes, opens out a vast field for the demand of charcoal and this opportunity should therefore, never be lost sight of.

6. The bark in some form or the other is used in the Tanning Industry.

7. The bark of the tree after it is dried and powdered is used with other adulterants for tooth-powder. This

powder is said to give a strengthening effect to the gum of the teeth. The water obtained after boiling the bark in it is used as a mouth gargle or wash and is said to act as a deodorant and an antiseptic.

8. The gum secreted by the tree has not only good sticking properties, but also serves as a strengthening medium of many other substances. The purified form of this gum is used as solvent for mixtures of sodium bicarbonate, magnesium sulphate, etc. The crude unsullied essence of Babul known as 'Acacia' has the virtue of healing many ailments.

This system of research besides opening out many other avenues and advantages to the villager, will materially go to solve his quest for fuel which is the main theme of this paper. The deplorably undernourished soils, can then be fed with cowdung to improve their fertility, and though the main bulk of the people are Agriculturists, yet they do not seem to devote any thought to this vital problem of self aggrandisement.

It may not be out of place to mention, that, even if the villagers come to a stage of affording the purchase of artificial manures for use in their fields, it cannot fairly well replace this natural manure, since the former cannot equal the qualities of the latter.

The method by which this system is to be carried out has already been suggested, *i.e.*, the acquisition of waste lands if any near the villages, the nala banks and the sides of country tracks and sometimes trunk roads to the extent of land available.

Stabilisation of the System.

In order to create a source of encouragement in the villagers it would be better if the Government relinquish their hold over the trees so planted and at the same time not impose any tax on these products so as to stabilise this system for the time being, when after the lapse of certain period the Government and as well as the people would both be benefited.

Control of the System.

The Revenue authorities who directly deal with the village officials and the villagers should be entrusted with this scheme and made responsible to see that the areas under their control are brought into such cultivation within a maximum period of five years.

A type of Babul known as ' Ram Babul ' should be encouraged to be planted as they yield better and straighter timber and can be planted closer because of their vertical growth, simulating the conifers.

Type of tree to be planted

In the Appendix is given a rough estimate of the number of trees that can thus be planted along nala banks and sides of tracks and the number of trees computed for cutting on maturity, to be available annually, and the increased income, the cultivator may look forward to.

Other indirect benefits to the country.

Besides the direct benefits that would accrue to the people and the Government as pointed out in detail in the foregoing paragraphs, there are other serious though indirect benefits that result from putting into operation this scheme.

Prevention of soil erosion A major factor for consideration

The major portion of the Deccan is covered by a more or less thick mantle of black soil, which during the summer months gets absolutely bare of vegetation, directly exposing the soil, with the result that the first few showers of the monsoonic rainfall wash away easily a considerable amount of this soil resulting in floods of highly muddy water in the nalas and rivers, A greater portion of this soil is thus lost annually, but other portions of it are slowly drifted to lower levels and eventually banked along rivers and nalas. This banked soil, by undermining and aided by rain gullies at the surface, is subsequently washed into the water and is thus gradually lost creating a condition for further accumulation of soil along the banks from time to time. The growth of Babul along banks of nalas and rivers, would therefore act as preventives against such soil erosion. The roots and root hairs would bind the soils more firmly in their places resulting in greater soakage of the rainwater which would otherwise run to waste. The undergrowth flourishes better, thus providing more food to the animals, and this growth has the further effect of arresting quick flow of rainwater, inducing in a further percolation of that water into the soil and sub-soil and rocks. The banked soil which by its relative position thus maintained would go to minimise the further soil erosion from the surrounding areas. As an instance of the amount of soil that is thus lost, an example given by Mr. R. Maclagan Gorrie* on soil erosion in India

* Soil erosion in India by R. Maclagan Gorrie, published in the Illustrated Weekly of India, November 10, 1940.

may be quoted: "One civil district, Jhelum, where cultivated land is being destroyed at the rate of 2½ square miles a year by a series of torrents which rise in the highly eroded and overgrazed Salt Range."

Trees planted along cart-tracks, would create similar results and the soil conserved. The soil erosion is a very serious problem facing the country as a whole, and it is feared that sooner or later most of this fine soil would eventually be lost exposing only bare rocks, as the formation of the soil does not go on *pari-passu* with the amount that is thus lost annually. I had elsewhere recommended the adoption of a system of field bunding, bush and terrace-growing or trench digging, to avoid this annual loss of soil, which is growing more alarming day by day, as the once huge forests have all been cleared, and even the little straggling and shrubby forests are now being cut off in a wholesale attempt at deforestation, thus aggravating the already existing alarming and serious problems.

Prevention of floods.

The vast undulating and treeless plains which are so common in the Deccan, give rise to sudden and frequent floods, due to the quick run off of major portion of even this insufficient rainfall, and if for some reason or the other, the rainfall should exceed the normal then that area would experience a devastating flood. This highly destructive and dangerous phenomenon would be minimised to a certain extent by the growth of these trees, which also indirectly aim at reforestation.

Formation of saline matter & other deleterious minerals prevented.

Again the nature of the soil and the highly arid conditions, combined with insufficient and insecure rainfall may give rise in the soil to saline matter and other deleterious minerals, which may prove injurious to agriculture. As in the greater portion of the Deccan the rainfall is limited and insufficient, and as the major portion of even this restricted rainfall is lost by quick surface runoff, there is no chance of these deleterious minerals in the soils being dissolved and carried by sub-surface waters. On the other hand, semi-arid conditions (induced by this loss of even scanty rainfall as surface runoff) result in injurious saline matter being brought up and deposited in the soil mantle often souring it. This limited percolation of rainwater to lower levels greatly affects the quality of the groundwater by taking into concentration large quantities of salts and making them unfit for potability. Hence there is a great diversity and disparity in

the nature of the sub-soil as well as the groundwater. Reforestation in general therefore, would by the combined advantages of giving rise to luxuriant undergrowth, greatly increase the 'intake' washing away during seepage the store of mineral matter in the sub-soil otherwise collected, and increasing the groundwater resources, yielding better types of potable water, which are at present often far too saline for drinking and domestic purposes.

The network of cart-tracks and the dendritic structure of the nalas, if developed in the manner described, would by the structure so formed, create a condition which would go to minimise the serious problems enumerated above, to a very great extent.

Increase in rainfall.

The present uncertain climatic conditions and the insufficient rainfall resulting sometimes in drought, appear to be the result of some regional desiccation, combined with the ruthless destruction of forests which have besides brought in all the grave problems mentioned above. The growth of these trees in partly aiming at the afforestation of the deforested areas, would improve the climatic condition as well as the rainfall in the area.

Luxuriant undergrowth particularly grass.

Incidentally it may be remarked, that the undergrowth, particularly the grass, will not only thrive longer, but grow more luxuriantly due to the conditions that are imposed by the growth of these trees in the manner described. This feature opens out a new avenue which may be taken advantage of, in the cultivation of such trees at regulated intervals in the Ramnas, *i.e.*, areas where natural grass grows. The chequered shade and the greater retention of soil at the places, formed by the growth of these trees, would besides other things, provide that much of optimum heat and sun's rays for the undergrowth of grass, to build up their necessary materials and thus yield a better and a greater harvest of grass.

Similarly the nude hill tops, where even amongst bare rocks some patches of soil if found, may be utilised in the growth of these trees to great advantage.

These methods, in addition to the main theme set forth in this paper, also aim at the reforestation of wide areas, which would very much minimise the alarming natural and

economic outlook facing the country at present, perhaps ushering in a new era in country life as a whole.

Lastly, it may be mentioned in general, that this scheme would open out new roads for employment of villagers and also to the otherwise workless agriculturists during the summer months, thus solving the question of rural unemployment to a certain extent.

In conclusion, I would particularly request the Government to devote their valuable attention to the scheme put forward and to usher it in practice at their earliest, so that the country may realise the full benefits in the shortest possible time.

A ROUGH ESTIMATE SHOWING THE NUMBER OF TREES THAT CAN BE PLANTED ALONG NALA BANKS AND CART-TRACKS.

The area of the State is 84,000 square miles comprising 16 districts. The average area for each district is therefore 5,250 square miles. Leaving two districts where no plantation is required due to the already existing forests and taking the remaining number of districts and to get at the total mileage of the nalas and cart-tracks therein, the case of Tuljapur, Georai and Raichur Taluqs are taken, in which as measured from topo sheets the average total length of nala and cart-tracks in a taluq were arrived at as 1,318 and 900 miles respectively. Therefore calculating on the basis of 73,500 square miles out of the total area of 84,000 square miles after deducting two district areas represented by the forest, the remaining length of nalas and cart-track available in the State works to 37,17,21,976 and 25,38,31,395 feet respectively. Taking the minimum of two rows on either side of the nala and the distance 10 feet apart and one row on either side of cart-tracks with the same distance from tree to tree, the number of trees that can thus be planted works to 14,86,88,790 and 5,07,66,279 respectively. So the total increase to the cultivator after the lapse of 15 years, assuming that only 1/15th of the total trees planted are cut for sale at the conservative rate of Re. 1 per tree is Rs. 132,97,004.

Number of trees that can be planted on nala banks.

Average total length of nala in a taluq:

$$\frac{1303\text{ (Tuljapur)} + 1279\text{ (Georai)} + 1371\text{ (Raichur)}}{3} = \frac{3953}{3}$$

$= 1,318$ miles or $1318 \times 1760 \times 3 = 69,59,040$ feet

Taking the length of nalas fit for cultivation of babul trees to be half of their total length in the taluq, the available length that may be utilised for cultivation would be:

$$\frac{69,59,040 \times 1}{2} = 34,79,520 \text{ feet.}$$

The average area of a taluq :—

$$\frac{784\text{ (Tuljapur)} + 624\text{ (Georai)} \times 656\text{ (Raichur)}}{3} = \frac{2064}{3} = 688$$

square miles.

The total area of the State is about 84,000 square miles and leaving aside two district areas representing roughly the extent of forest areas in the State, and computing it at $\frac{1}{8}$th of the total area of the State, the remaining area in which plantation can be undertaken is :—

$$84{,}000-\frac{84{,}000}{8}=84{,}000-10{,}500=73{,}500 \text{ square miles.}$$

The total length of the nalas available in the State for plantation will therefore be :—

$$\frac{34{,}79{,}520\times 73{,}500}{688}=37{,}17{,}21{,}976 \text{ feet.}$$

Taking two rows on either side of the nalas and planting trees at an average of 10 feet interval, the total number that can thus be planted would be :—

$$\frac{37{,}17{,}21{,}976\times 4}{2}=14{,}86{,}88{,}790 \text{ trees.}$$

Assuming that after the lapse of 15 years, 1/15th of the total number of trees planted can be cut off, the available yield per year will be :—

$$\frac{14{,}86{,}88{,}790}{15}=99{,}12{,}586 \text{ trees.}$$

Number of trees that can be planted on the sides of country tracks

Average total length of track in a taluq :—

$$\frac{947 \text{ (Raichur)}+855 \text{ (Tuljapur)}+900 \text{ (Georai)}}{3}=900 \text{ miles}$$

or 47,52,000 feet.

The average area of a taluq= 688 square miles.

Taking the length of tracks available for the plantation of Babul trees as half the total length of tracks in the taluq :

$$\frac{47{,}52{,}000\times 1}{2}=23{,}76{,}000 \text{ feet.}$$

The total area available is 73,500 square miles. Therefore the total length of tracks available in the State :—

$$23{,}76{,}000\times 73{,}500=25{,}38{,}31{,}395 \text{ feet.}$$

Taking one row on either side of the tracks for planting trees at 10 feet interval, the total number of trees that may thus be planted would be:—

$$\frac{25{,}38{,}31{,}395 \times 2}{10} = 5{,}07{,}66{,}279 \text{ trees.}$$

Assuming that after the lapse of 15 years that 1/15th of the total number of trees planted can be cut off, the number of trees available per annum would be:—

$$\frac{5{,}07{,}66{,}279}{15} = 33{,}84{,}418 \text{ trees.}$$

Thus the total number of trees that are annually available for sale:

Nala Banks	..	.. 99,12,586 trees
Cart Tracks	..	.. 33,84,418 ,,
	Total	..1,32,97,004 ,,

Taking the most conservative figure of Re. 1 per tree, the total increase in the annual income to the country will be Rs. 1,32,97,004.

APPENDIX II.

Advisability of effecting land improvement in the Hyderabad State by means of field embankment system.

Advisability of effecting Land Improvement in The Hyderabad State by means of Field Embankment System.

Geological & Physiographic Features of the Dominions.

It is an interesting feature that the linguistic grouping of H.E.H. the Nizam's Dominions into Telangana, Karnatak and Marathwara shows close correspondence to three distinct geological and physiographic units. The features of these three units can briefly be narrated as below :

Telangana which is covered with the granitoid gneisses of the Peninsular Complex, sedimentary formations of the Purana and Aryan groups (Gondwana) is mantled by loamy soil requiring and capable of taking large quantities of water for irrigational purpose. The country is more or less flat, separated by ranges of knolls and masifs of hills. Suitable depressions have been bunded from time immemorial to form tanks for irrigation.

Karnatak which borders Marathwara to the North and Telangana to the East is covered with the Archæon formations, Purana rocks as well as deccan traps, and has features dominantly analogous to those of Marathwara, in that the mantle that covers even the earlier geological formations is black soil which is highly fertile and does not bear watering.

Marathwara is covered almost entirely by the deccan traps with a thick mantle of black soil. The deccan traps yield but little mineral wealth and their greatest asset is the soil formed through weathering and which is ever rich and fertile responding luxuriously to seasonal rains.

It can be inferred from the above description that the soil in Telangana country is inferior in fertility, and therefore artificial watering is generally a necessity. As luckily the country is well suited for the formation of tanks, irrigation is mostly done by the tank system. The subject of field embankments does not therefore pertain very much to this portion of the Dominions, and consequently attention is diverted to the other two groups of the State, Karnatak and

Marathwara, where black soil predominates and where neither the country nor the soils are suited for the formation of larger tanks.

Origin and characters of black cotton soil.

The origin of black cotton soil has been the subject matter of study of soil-scientists in tropical and sub-tropical countries. Several theories have been advanced on the subject and without going into their details it may be mentioned that it is now widely recognised, based on the classical work of Robinson and Sivan (Memoirs of the Imperial Agricultural Department), that the *B.C.* soil owes its property mainly to the minute colloidal dimensions into which it disintegrates. The older views that the black colour of the soil was due to titanium or iron or humus is not now accepted and the colloidal dimensions of the particles are known to account for the black colour—a phenomenon familiar to physical chemists. A minute study of the formation of *B.C.* soil in the field reveals the stages of the formation of this soil from the red or loamy soil. The breaking up of the loamy soil into minute dimensions is controlled mainly by the processes of weathering induced by diurnal and seasonal changes of temperature, aridity, rainfall, etc. The *B.C.* soil is capable of absorbing large quantities of water and conserving them over a long period. This property results in making agriculture independent of artificial irrigation, provided the area experiences normal seasonal rains.

Transportation and migration of black cotton soil

On account of the fineness of the individual particle in the *B.C.* soil area, it is easily transported by æolian agencies ; and torrential rains specially along slopes constitute an equally effective agency of soil transport. The part played by these factors has an important bearing in any measure contemplated to check the menace of soil erosion.

Geological factors.

The deccan traps consist of successive solidified lava flows more or less horizontal in disposition. Though the lava was originally basaltic in composition the physical characters of the various layers differ greatly ; some of them are hard and massive, others weather into scaly or exfoliating types leaving a hard central core and yet others have become comparatively soft and friable. A deccan trap country presents a stepped aspect ; a flat country suddenly ending in a steep escarpment giving rise to another flat country lower down. A careful examination of such areas proves that flat-topped plateaux

are the result of a protective hard layer of trap. Beyond the escarpment, there is a rapid erosion of the lower and softer strata till the next hard trap layer is exposed. In contrast to the nearly flat-topped areas where harder layers are exposed, the country of the softer strata gives rise to frequent undulations and in such areas, soil erosion takes place very rapidly. This is a greater misfortune as generally such areas constitute protected valleys capable of supporting good garden crops.

Effects of deforestation.

Till recent times, a good part of the State was covered either with sub-tropical forests or by shrubby jungles. That this was the case within the living memory and that deforestation has progressed with phenomenal rapidity due to a variety of causes is a fact too well known to require emphasis here. The function of forests and shrubby vegetation is to prevent transportation of soil by æolian and aqueous agencies. Once this protective source is removed, soil erosion progresses rapidly converting a once fertile area into barren and screenrich wastes.

From a study of soil erosion by the Bombay Dry Farming Research Station at Sholapur, it is estimated that sometimes there is as much as a loss of 133 tons of soil per acre per annum in jawary growing fields. A torrential rain about 2 inches in an hour is recorded to have removed 50 tons of soil in an area of one acre which might be considered to have been nearly flat. In spite of increasing the quality of seed and agricultural methods, there could be no prosperity to the ryots unless measures are taken to combat the scourge of soil erosion.

Bunding.

As pointed out by experts on this subject the best method of stopping the annual migration of soil, is by a series of field bunds. In due course, these embankments are meant to check surface erosion, to make lands level, to hold up rain water and to control water courses for effecting large distribution of soil and water in the fields. The ignorant ryot does not realise this betimes. He opens his eyes only when the whole of his field is actually denuded by continuous washing off. Sporadic attempts on his part to reclaim the washed off lands become too late, which is chiefly due to (1) little or no foresight, (2) want of funds. Land development by embankments is a permanent improvement and costs a good deal. Therefore funds at cheaper rate of interest are required ; (3) absence of technical knowledge—instances are not rare where people have struggled

throughout their life to put successful bunds by spending large sums of money.

To lay out efficient bunds, technical knowledge is absolutely necessary. Control of water courses should be based on the sound principles of water discharge calculations. An Indian cultivator is helpless in this respect. He depends upon his naked eye and his experience ; and even then his is a guess work. Naturally this results in failures which are always disastrous and dishearten the poor who ventures to undertake such works on Takkavi loans. Unless, therefore, the annual denudation now going on is checked with the active co-operation of the ryot and the Government and that too soon, both stand to lose by large areas going practically out of cultivation.

Experiments and schemes conducted in Bombay Presidency.

In consideration of the above, the problem was seriously taken up in the Bombay Presidency on an experimental basis in 1922. Work was first started in the Dharwar division, and with the successful results achieved there, it was subsequently extended to the Nasik division in 1929. In the course of 7 years, about 600 schemes were carried out. Takkavi loans were made available on a large scale through Co-operative banks, and the Revenue Department on nil or low rate of interest. The cost of improvement of the fields varied from Rs. 15 to 25 per acre. Returns varying from 10 to 20 per cent. on the investment were realised. It is said that in some cases the profits were as much as 200 per cent. on the investment. A substantial increase in the returns is visible after about 2 years.

In Dharwar and Bijapur where the nature of the soil is similar to that of the Karnatic Districts of the Hyderabad State, the profits were calculated from the results of about 15 bunded fields, each field consisting of an average area of 40 acres. These 15 fields composed of first class, 2nd class and 3rd class bunded fields. The returns before the bunds were put up were Rs. 19 per acre, but after bunding, the returns increased in varying degrees to Rs. 30 for 3rd class, Rs. 49 for 2nd class and Rs. 78 for first class, per acre of the bunded field of the flooded area and the cost of the scheme for putting up the bunds varied also per acre from Rs. 100 to Rs. 300, From this it is apparent that higher the initial outlay, the higher and earlier is the return. As already mentioned the flooded area being about 1/10th of the total area of the field, the cost per acre of the bunded fields works out

to Rs. 10 to Rs. 30, per acre and the increase in crop is therefore estimated to be more at least by 25 per cent. of the yield than that of an unbunded field.

The advantages of bunding are many:

Advantages of bunding.

(*i*) The fine particles of earth formed yearly from the disintegration of the plateau rocks, instead of being swept away down the slopes into the rivers by the rush of the monsoon rains are collected by the bunds. Thus each succeeding year it adds to the depth of the soil behind the bunds which acts as a top dressing and manure.

(*ii*) These bunds conserve the rain water and the spring water which flow for two months after the rains instead of allowing them to run off unchecked into the main drainage systems of the country, thereby effecting a rich growth of crop both on the upstream and downstream sides of the bund.

(*iii*) The friction to the underground flow of water is increased and the rain and spring water are conserved in the higher terraces and slowly percolate down the slope; and by supplying increased friction will, it is estimated, last even in droughts to a certain extent.

Method of bunding.

Bunding of the fields is done by actually surveying and levelling the fields. The bunds are laid on contour line. The methods to be adopted are:

(*i*) The bund should not be designed to store water to a great depth, but it should be to hold shallow depths of water over a maximum possible area of land, so that the silt is deposited and moisture stored over this area.

(*ii*) The water-spread area must be as big as possible. Therefore, it is quite necessary to study the physiographic conditions, such as the catchment area, slope of the country and its relation to the natural drainage, etc.

(*iii*) Each block of field belonging to one cultivator should be bunded preferably as a separate unit.

For the purpose of survey, the area is divided into blocks and pegs are driven at the corners of these and they are numbered. Levels are taken at the position of these pegs. These are then plotted and contour lines and water courses are drawn.

(*iv*) The position of bunds is then determined coinciding almost with the contour lines.

Though it is not possible in practice to exactly follow the contour for the formation of bunds, yet it is possible to straighten the contour lines by joining two suitable points on it, so that the bund line does not go much astray from the contour line. (Please see the attached plan).

In America, however, it is understood, that the bunds are put up to exactly coincide the contour lines, which method it seems, does not present them with any difficulty.

The advantages of contour bunds over other methods of bunding are :

Advantages of Contour bunds.

(*i*) The expense, time and energy required for levelling the undulations of the field are saved.

(*ii*) As the bottom of the bund throughout its length is almost at the same level, the pressure of water on the bund is quite uniform as a result of which the fear of breach of the bund is almost negligible.

(*iii*) As the height of the bund is very small, the cost of bunding is very much reduced.

(*iv*) The rate of silting up is fast and the fields are levelled earlier.

(*v*) As the bottom width of the bund is uniform, much of the technical direction required to mark out the bunds is saved, and the work progresses fast.

Position of bunds

The position of a bund is not fixed on the horizontal distance, but on the difference in levels between two successive contours. This difference is usually between 3 to 5 feet depending upon the slope of the country. It is the usual practice to construct the bunds starting from the highest contour to the lowest contour and the area of bunded compartment is usually kept at about 8 to 10 acres.

The contour bunds should extend from one edge of the field to the other, or from one ridge to the other.

Waste weirs.

Having decided upon the position and section of the bunds, the waste weirs should be so designed that they are not only economical in construction but are also capable of discharging surplus water from the full catchment area. The main purpose of

bunding as already stated is not to hold up water, but to deposit silt in the bed of the field and the collected water to seep gradually downwards and therefore it is not necessary to construct bunds water-tight, in the sense that irrigation tank bunds are usually constructed. In designing a waste-weir, the total catchment area above the field bund should be taken into consideration. Catchment area, run-off and the slope and nature of the country should be closely studied for calculating the length and flanks of the weir, which can be constructed either of pucca stone masonry in mortar, or of dry stones. In the section enclosed are given the lengths of dry stone weirs and the heights of discharges over them for different catchment areas.

In a series of parallel bunds, if the weir of one bund is provided on the right flank, the weir of the adjacent bund above or below it, should have the weir on the left flank. This has the advantage of spreading the water in the field next below, besides stopping the formation of deep nalas.

The flanks of the weir should not be square but rounded as shown. They should be constructed up to about 1½ to 2 feet above the discharge level of water over the crest of the weir.

If the body wall of the weir is to be built of dry stones, its height should not be more than 4 feet. For this height, the body wall should be at least 3½ to 4 feet wide at the bottom and 2½ to 3 feet at the top or crest level, *i.e.*, starting from the crest, the width of the wall should be increased by 3 inches for every foot depth.

In course of years as the level of the fields rises due to the deposit of silt, forming ultimately terraces, it will be necessary to raise the heights of bunds and weirs.

In deciding the nature of the construction of a weir, it should be noted that if the catchment area exceeds 400 acres a pucca masonry weir is advisable. In the enclosed diagrams the lengths of such masonry weirs and the heights of discharges over them, for different catchment areas are given.

The free board over the flanks should be about 2 feet so as to safeguard the bund against unexpected rush of water. If the catchment area exceeds 1 square mile (640 acres), the free board should preferably be 3 feet.

Having thus fixed the position of the weir the height of the bund is calculated as follows:

Section of Bund.—The height of the bund equals the height of the weir wall, plus height of flanks, plus free board.

The minimum height of a bund should not be less than 3 to 3½ feet.

After the height of the bund is calculated the top width of the bund should first be decided. This usually varies from 1½ to 6 feet according to the height. But for purposes of field embankments, it is enough if it is kept at only 1½ feet. It can even be reduced to 1 foot if the soil is mooram or hard soil. In hard soil the upstream side slope of a bund is usually kept at 1 to 1 and on the downstream side 1½ to 1. For method of construction please see the enclosed plan and sections.

Preservation of Bunds.—These bunds which are gradually eroded and ultimately reduced to the level of the accumulated silt above, may be effectively preserved for a much longer time by growing on these bunds the Species of Agave Sisalana introduced into Commerce in Mexico in 1839 and named from the small port of Sisal in Yucatan whence it was first exported.

The bushy adventitious roots while not interfering with the cultivated plants, will firmly hold the bunded soil and prevent it from erosion. The long succulent leaves which cast shadows a little beyond their own limits, do not interfere with the sunlight that is needed for the cultivated plants.

Besides the great advantage mentioned above the growth of these plants will open out a vast field for a useful new Industry which may add to the national wealth of the country and also provide the much-needed material to the cultivator.

These plants are extensively grown in Mexico, Central and South America, the West Indies and Bahamas and particularly in East Africa, India, Indo-China and Philippines. The fibre removed from machinery is in strands, 3 to 5 feet long, nearly white, stronger and woollier than hemp. Such ropes as known to everyone are useful in a variety of ways where strength and durability are needed involving wear and tear.

Success of Bunding.—This depends upon the following five factors :

1. Correct planning both for Agricultural and Engineering points of view.

2. Availability of cheap and good building materials.

3. Execution and construction of the work under fairly intelligent guidance.

4. Periodical repairs to the bunds.

5. Raising the bunds and the weirs, as the field is raised and levelled up by the accumulation of silt.

As lands in the Karnatic are much more undulated than in the Marathwara, Mr. Raj Dev, Deputy Director, Agriculture Department, is of the opinion that on an average the cost of bunding one acre inclusive of technical supervision will be Rs. 15 in the Karnatak and Rs. 10 in the Marathwara.

The supervising staff should consist of

		Rs.	a.	p.
1.	Salary and allowance of one trained Overseer (Designated as Bunding Officer) Rs. 124+25	=149	0	0
2.	Salary and allowance of 3 Sub-overseers Rs. 65+15=80	=240	0	0
3.	Salary of three maistries Rs. 25×3=75 ..	= 75	0	0
4.	Salary of 4 Khalasis at Rs. 12×4=48 ..	= 48	0	0
5.	Stationery, etc :—	= 13	0	0
	Total ..	525	0	0

Non-recurring :

Levelling instrument and drawing equipments, etc.	1,000	0	0
Agricultural equipments :	1,000	0	0

The non-recurring expenses should be deferred by the Government in view of the indirect returns that the Government will realise after the lands are improved. The party as composed above can supervise and mark out bunds in an area of 2 to 3 thousand acres in one year.

Along with the introduction of laying out of field bunds on scientific basis, advantage should be taken to introduce latest types of agricultural machines. Of these, I saw in Raichur Experimental Farm two types of machines which are cheap and useful for conserving water in the fields and stopping erosion.

One is called Bund Farmer. It costs B.G. Rs. 22 plus about B.G. Rs. 4 for freight, etc. This is obtainable from the

Agricultural Engineer, Government of Madras, Coimbatore. The machine forms bunds one foot high and the formation of such bunds parallel to the field embankments will increase the fertility of the lands enormously.

The other type is called Basin Lister, which costs B.G. Rs. 30 plus about Rs. 4 for freight, etc. It is obtainable from Messrs. Cooper and Co., Satara. With this machine furrows are made at every 4 feet or so, a small ditch is formed. These furrows and ditches conserve and soak water into the lands and thus increase the fertility of the soil.

The Government should lend these machines free of rent to the ryots. As in the case of iron ploughs, once the ryot realises the advantages accruing from the use of these machines, it will not take long for him to adopt them, especially when the initial outlay is small and the power required to work them is only a pair of bulls.

Method of Financing

Excluding the establishment charges, which the Government should at the outset bear the cost of bunding per acre on an average will cost Rs. 10. These expenses can be advanced to the ryots in four ways : (*i*) Out of the savings of the cultivator, (*ii*) loans from the village sowcars, (*iii*) loans from the Co-operative Societies, (*iv*) Taccavi loans from the Revenue Department.

Those of the field owners who are rich should pay for the expenses from their savings. But those whose income is limited, should be granted Taccavi loans by the Revenue Department without interest on long-term instalments, say eleven years recoverable in 10 instalments—the first instalment being made from the produce realised in the second year as in the first year of bunding the results are not very marked.

No. (*ii*) involves high rate of interest and is too complicated for the illiterate ryot. No. (*iii*) cannot finance such long-term loans, besides the ryot cannot pay even the small rate of interest.

Method of working

It will be the duty of the Bunding Officer to select the fields for embankments. This having been done the sub-overseers should level and plot them and mark the position of contour bunds on the fields and show them to the field owner for putting up the bunds. Further labour required (khalasis) for taking the levels, pro-

viding and fixing pegs, etc., should if need be supplied by the field owner.

The Survey and Construction can only be done when there are no crops in the field. Therefore the bunding Party will work on the Khariff lands when there is Rabi crop and vice versa. The Party will not however be able to work in the months of September and October, as during these two months, both the Khariff and Rabi crops will be standing.

After the mark-out has been given for the bunds and weirs, the field owner should arrange for the labour at the fixed rates. The Taccavi loan should not be handed over to the field owner but the Bunding Party, should pay to the labour employed on the work as per measurements taken by the Overseer for the work done, else it will result not only in inefficient work, but also the money if advanced in a lumpsum to the field owner will be diverted to other channels of expenditure other than for which it is meant.

The money should be drawn from the treasury once a week or fortnight, as may be convenient and paid to the labourers preferably in the presence of a Revenue Officer and the field owner.

Sufficient propaganda has also to be made among the ryots that unless they co-operate with the Government for construction and maintenance of bunds, the money so advanced by the Government will absolutely go to waste.

Conclusion

With thanks to Mr. Raj Dev and his assistant Mr. V. K. Kulkarni, B. Ag., for having furnished the required information, I conclude this report by reproducing the remarks on field bunding of Late Captain L. Munn from his book on the Geology of Underground Water Conditions in Osmanabad District—" This proposition, I am sure, is well worth the Revenue Secretary's careful consideration and from a financial point of view must be a more paying investment than any tank project."

Statement showing the length of dry store weirs and heights of discharge over them for different catchment areas

Catchment area in Acres	Length of weir in feet for normal rains	Height of discharge in feet	Remarks
100	25 17	1 1	As a precautionary measure in case of abnormal rains, it is always safe to raise the height of the flanks by about 2 feet.
200	50 34	1 1½	
300	75 50	1 1½	
400	100 68	1 1½	
640 (1 sq. mile)	50 38	2½ 3	
1,280 (2 sq. miles)	94 72	2½ 3	
1,920 (3 sq. miles)	133 102	2½ 3	
2,560 (4 sq miles)	167 128	2½ 3	
3,200 (5 sq miles)	197 151	2½ 3	

APPENDIX III.

REPORT ON THE FORMATION OF BOGS UNDER NIZAMSAGAR PROJECT

Report on the Formation of Bogs under Nizamsagar Project.

Introduction.

In compliance with the wishes of Hon'ble the P.W.D. Member and as approved by the Hon'ble the Revenue Member conveyed to me in Revenue Secretary's letter No. 64, dated 26-1-1354 F., (Oct: 1944) I visited the Bog area near Bodhan Sugar Factory to investigate the formation of Bogs, and to suggest if possible remedial measures. Dr. A. M. Heron, Director of Mines & Geological Survey Departments kindly permitted Dr. C. Mahadevan of the Geological Survey Department to accompany me during this investigation to advise on the geological aspects of the problem. I met Mr. J. C. Hardiker, Executive Engineer, Nizamsagar at Nizamabad on 22nd Dai 1354 F. (Nov: 1944) and we left the next day to Bodhan where investigations were carried out by me from 23rd to 27th Dai 1354 F. (Nov: 1944) with the help of the Research Staff of the Bodhan Sugar Factory and some staff of the P.W.D.

Preliminary considerations.

Ever since the introduction of heavy irrigation in India the problem of water logging and the consequent alkalinisation of the soil has confronted the Irrigation Engineer and the Agriculturist. Numerous investigations on the different aspects of the problem have been carried out by Engineers, Geologists, Soil Physists and Chemists. I need not go here into a review of the learned and useful publications by most of these observers on the problem, as it is recognized that, apart from the fundamentals, each case has to be dealt with locally on its own merits and environmental factors.

The soil and sub-soil conditions in the area prior to the introduction of irrigation.

In the Deccan, covered with black cotton soil, due to the arid and semi-arid conditions and the peculiarities and eccentricities of rainfall and its nature of distribution, a sort of soil blanket consisting of Chlorides, Sulphates and Carbonates of Calcium, Sodium, and to a minor extent, Magnesium is formed mixed with the finest particles of clay. This goes by the name of Reh, Kallar or Choupan. This blanket has often, specially when moist, a yellowish colour. Normally in such arid and semi-arid areas, the water-table is much below this layer and as mostly dry cultivation is resorted to in such lands, this blanket plays but little part in the actual agricultural operations. The thickness of this layer is a variable factor and it is anything from less than a foot to as much as six or seven feet. When, due to soil erosion, this layer is exposed, it appears mostly as pale yellow or whitish

crust —usually called the hard pan—with saline efflorescence on the surface. There has been almost a universal recognition all over the Deccan, including parts of Bombay Presidency, of the loss of cultivable land due to the denudation of the soil and the exposure of this crust on which nothing but some saline grass and halophytic plants grow. Below the crust or hard pan, is the sub-soil or decomposed rock. Due to gravitation of water towards valleys and the rising of water-table in the valley portions, this concretionary layer of alkaline material is found to be thicker than on water sheds or level country.

Effects of heavy Irrigation.

The effect of heavily irrigating such areas has resulted in certain local pockets, in forming bogs (Phodas), besides rendering parts of the soil alkaline and unfit for cultivation. The layer below the soil is already alkaline and the waters which are themselves sligtly alkaline (as disclosed by analysis), when put into the fields, add to the salinity or alkalinity of the soil, and the layer below it.

Seepage from unlined distributaries.

The unlined distributaries of the irrigation system account for a good deal of seepage of the water to the subsurface, raising the water-table over its entire length. The sub-distributaries and field channels add to such seepage, raising the water-table further. Heavy irrigation of the crops also contributes to this rise in the water-table. Even if the unlined distributaries, the drainage channels, and the fields are carefully looked after from the point of view of free surface drainage, there are ample conditions present to raise the water-table considerably. Physiography or the surface configuration also adds to the complexity of the problem. The cumulative effect of all these factors is to disturb nature's equilibrium, established as a result of centuries of adjustment of climatic and soil conditions.

Remedial measures have to be thought out to minimize the complications arising out of the introduction of heavy irrigation in such areas.

Mechanism of the Formation of Bogs (Phodas).

During the course of my investigations, a very careful study of the physiographic conditions of the areas, such as the slope of the ground, the position of the water-shed, the relation of the valley to the water shed and the tanks, the

effect of the partial breaching of the tank, etc., was made. The existing bogs (phodas) were then examined. Eight pits, in carefully selected places right to the bottom of the porous moorum layer, well below the blanket were put, to study the condition of the soil, the blanket, the sub-soil and underground drainage. These pits are located from very near the water shed near the main distributary through the valley, down to the bed of the tank, marked 'kunta'. The location of these pits as well as a transfer section of this profile and the logs of the pits are given in the appended blue print.

It will be seen from the examination of the logs that in Pit No. 1 there is a fairly thick soil of clay which is underlain by a yellowish muck. Below this is a layer of yellowish muck mixed with moorum, and finally decomposed rock or moorum soil is met with. Water was met in the moorum soil. In Pit No. 2 which is located about 900 feet further down the valley there is clay tinged with alkaline soil down to about 5 feet from surface. Below this is yellowish muck mixed with moorum. This is underlain by the porous moorum soil. The water-table was encountered at about 10 feet from the surface in the porous moorum. Pit No. 3 about 240 feet further down in the valley has a layer of about 2 feet 9 inches of alkaline clay which is underlain by the yellowish muck which is mixed with moorum further down to a depth of 9 feet 10 inches from the surface. Under this is the moorum layer. Water was met in this last moorum layer. Pit No. 4 is very near the Railway line about 500 feet from Pit No. 3 and in the area of the bog.

Some interesting observations were made here during excavation. The pit was located in what appeared to be a dry ground between two bogs. As the excavation proceeded into the layer of the yellowish muck there was a gradual inflow of saturated slimy yellowish muck from the adjoining bog. A considerable quantity of this was taken out with a view to reach the bottom layer if possible. Due to this influx of mud into this pit from the adjoining bog we could not excavate it down to the moorum layer. As may be seen from the section the yellowish muck starts almost from the surface. Pit No. 5 which is just adjacent to the bog area shows alkaline clay and yellowish muck down to 9 feet 6 inches from the surface. It was excavated to a depth of about 2 feet in the moorum layers reaching to a total depth of 11 feet 6 inches. Water was met with at 11 feet 3 inches. It may here be interesting to point out that as a good part

of the sub-surface water has been utilized through capillary action and saturation by the alkaline layers to form bogs, there was not a heavy rush of water and the consequent rise of water-level in the pit was as normally expected.

Pits No. 6 and 7 were located practically in the bed of the tank and the conditions of sub-soil are deserving of some comments. It has been pointed out in the earlier paragraphs that the formation of a blanket of impervious salts was the result of semi-arid conditions and alternate saturation and dessication of the soil and sub-soil profiles. In proximity to the bed of the tank there is adequate water to wash down the salts to the sub-surface on account of which we find below the silt (the transported soil) a moorum layer. These pits, as may be seen from the survey plan are away from the natural valley. In pit No. 8 which is almost in the natural valley there is some alkaline material below the clay and concretions of kunkar.

The Officer in-Charge of the Sugar Factory Research Department, Mr. Kazmi, his assistant Mr. Joshi and other members of the staff gave me their whole-hearted co-operation in these investigations. We had, besides, the advantage of the analyses of the soils and the blanket layers of this area, and their PH value given to us either from their recorded results or made at our request during our investigation. Some salient features connected with these results may be briefly described here.

The PH value of all these soils and the blanket layer is between 8 and 9, *i.e.*, highly alkaline. In the profile the sodium content varies from about 3 to 18 per cent., the Magnesium from about 1 to 7 per cent., and the Calcium from about 12 to 77 per cent. The available calcium is extremely low for plant growth. In effect, these are typical alkaline soils incapable of supporting cultivation. It is not intended to digress here into the detailed examination of these chemical analyses except in so far as they are relevant for the purpose of the understanding of the mechanism of the formations of the phodas.

Genesis of Phodas.

From an observation of the location of the phodas it is seen that they are confined to certain valley portions in the areas. Let us visualise the effect of heavily irrigating an area with a top soil of clay separated from the pervious layer of porous moorum by a layer of blanket consisting of concretionary alkaline salts heavily mixed with finest colloidal particles

of clay. Due to the seepage from the system of unlined distributaries, field channels and surplus from the fields, the water-table in the area rises considerably and comes up to the top of the moorum layer. Generally speaking the profile of the water-table is more or less parallel to the profile of the surface, and this is to some extent controlled by the thickness of the blanket layer and the nature of the decomposed substratum. The tendency for sub-surface water is to gravitate towards the valley almost in the same manner as a surface water tends to find its course to the valley. In the water shed area, there is thus always a great tendency for sub-surface water not to stagnate but to move down towards the valley. If the valley has proper surface and sub-surface drainage it will gradually be carried off to the adjacent deepest valley. But this is often not so due to the bunding of the valleys for the construction of tanks and for similar other reasons.

Water-logging is greatly facilitated in such imperfectly drained depressions. When the water-table rises up to the moorum layer, it comes into contact with the impervious blanket, which, as has already been explained, consists of the finest colloidal particles in combination with the salts of sodium, calcium and magnesium. This layer gradually begins, through capillary action, and saturation, to imbibe the water. On account of its finest particle size, it is capable of taking very large quantities of water in physico-chemical state, being a colloid. The sub-surface water, through capillarity, thus gradually begins to be absorbed and adsorbed by pockets of the blanket and increases considerably in volume. Mr. Joshi found at our request, that this material in its plastic state, absorbs from 200 per cent. to 300 per cent. of its own weight of water. When the whole layer, almost right up to the surface, is thus saturated with water, it becomes a slush with an enormous increase of its volume. It then wells up and grows rapidly above the surface like a volcanic cone. The top-most layers, on exposure to air and sun, dry up rapidly. The growth of a bog or phoda can thus be easily watched and even measured.

The central part or the basin of the bog consists, while it is still growing, of the slimy matter, whereas the sides are hardened by drying. It looks like a volcano in shape and mechanism. If the sides of the bogs (phodas) are punctured, the slushy material flows out and spreads in its viscous state, like a lava flow, giving rise to polygonal cracks as it dries up

on the surface. After this escape of the slush to the sides there is a general subsidence of the welled up portion. Cracks are developed on the dried up sides. It is interesting to record here that during the digging of a pit between two bogs (phodas) near No. 5 Pit, as the coolies were excavating in the blanket layer, there was a sudden release of the slush from the adjoining phodas resulting in one of the coolies nearly being engulfed by it. He was luckily pulled out by his comrades. Near Pit No. 4, it was similarly observed that, as the excavation was proceeding in the pit adjacent to that phoda, the material gradually began to ooze in, and the volume of earth thrown out on the surface was considerably more than that which originally belonged to the pit. We could not deepen here to the moorum layer due to the inflow of the material from the adjacent bog.

It will thus be seen that the phodas are caused in the valleys, where due to the imperfect surface and sub-surface drainage, water-logging takes place from the raised water-table which saturates the impervious yellowish alkaline layer giving rise to pockets of slushy material. Due to the enormous increase in volume of the alkaline salts mixed with clay these pockets well up to the surface, building up cones with craters, much in the manner of volcanoes.

It may here be mentioned that not all the ayacut of the Nizamsagar canal area is covered by black cotton soil. In fact a good percentage of the irrigable lands consist of sandy loams, *i.e.*, porous soil. The impervious blankets are not met with in such areas, and consequently, there is no apprehension of the formation of bogs here. Even in such areas, uncontrolled and indiscriminate irrigation may give rise to the introduction of alkaline salts which are detrimental to soil fertility.

At first I was given to understand that only a small area of about 50 acres of land in the Bodhan Sugar Factory property was affected by the bogs. On further enquiry I learn that every valley in this area has been similarly affected. I visited two other places amidst the thickly cultivated sugar fields where similar conditions exist. Surface drainage here was very unsatisfactory due to the growth of weeds (Tunga grass) and vegetation, and the unattended conditions of the field channels. It was also noticed that there was a good amount of excessive water flowing out of the fields. Potential Phoda lands can easily be distinguished and isolated by the presence of Tunga grass and certain other plants, a thick

efflorescence of salts on the surface, and the hard pan or the exposed crust. When a small lump of this is placed in water it swells up enormously and forms a sort of slimy slush.

On careful enquiry I learn that almost all over the irrigated area under the Nizamsagar Canal, where there is black cotton soil with a blanket of alkaline material, bogs have begun to develop in valleys with imperfect drainage. If the problem is tackled early we can practically isolate the bog forming areas and adopt remedial measures to prevent their spread. If this is not done and the bogs are allowed to develop indefinitely there is very little doubt that they will spread on through the levelled areas ultimately to the water-shed also. It is well to recognize the seriousness of the problem and not deal with it half heartedly. In other parts of India they had to pay very heavily due to the neglect of this problem in its early stages. We may learn from their experience.

Remedial measures.

During my stay at Bodhan I had opportunities of looking into some reports by Messrs. Sahasrabudhay, Joshi, and Kanitkar and also by Messrs. Joshi and Vasudevan of the Research Department of the Sugar Factory. It is not my purpose to go into a critical examination of the reports or to concern myself with the measures suggested by them *for the reclamation of the already affected areas.* My object in this note is to confine myself exclusively to suggestions of preventive measures, to minimize the effects already produced, and to prevent further areas being involved in this ruinous transformation. I estimate on a conservative scale that over 1000 acres of irrigable and cultivable lands are already affected in different stages by this menace, and it is almost certain to expand rather rapidly, if neglected. In my opinion, the following measures have to be taken effectively and promptly to deal with the problem :

1. The lining of the main and sub-distributaries.

2. The effective control of the drainage of the field channels in the irrigated areas with penal clauses for the infringement of regulations laid down to secure this end.

3. The breaching of the old tanks where required and levelling up of the tank-bund not to interfere with the natural drainage of any area.

4. The maintenance of the surface drainage through natural valleys to see that surface water reaches effectively the lowest and main valley without obstruction.

5. Provision for the immediate sub-soil drainage in the water-logged areas, to facilitate an easy flow of water in the moorum soil. This sub-soil drainage has to begin at the commencement of the valley and be taken right down to the required depth in the deepest main valley. This may be done either as an open channel or as a tile, or stoneware drain as has been the case in similar water-logged areas in the U.S.A. and Egypt.

6. The ample provision of culverts and water channels in areas where bunding has been resorted to, either for laying trolley lines, roads or for even canals or main distributaries so as not to interfere with the natural drainage and thus give rise to stagnant surface water.

7. The prevention of indiscriminate excavations without arranging for proper drainage either for purposes of bunding or for levelling of ground for cultivation.

8. If the natural valleys do not facilitate a healthy drainage of the soil and sub-soil, deep wells have to be excavated at suitable places from where water can be pumped out to prevent water-logging. This water can easily be utilized again for irrigation. With the availability of power from the Nizamsagar canal, this aspect should not present any difficulty.

9. As far as possible, the natural valleys and the near approaches should be reserved for dry cultivation, thus minimizing heavy water being put into areas where natural conditions already tend towards bog formations.

10. The judicious rotation of heavily and moderately irrigated crops and dry crops will have to be seriously thought out to mitigate not only the problem of water-logging but to conserve soil fertility. Subjecting a field to a heavy continuous irrigation results in the adding up to the large amount of alkaline material already present in the soil. The beneficial effects of such a rotation have been sufficiently emphasised by soil chemist.

11. The channels, to facilitate sub-soil drainage, should be excavated deep enough to get into pervious soil by about 2 feet in order to draw the seepage into it. The excess of surface water from the fields will have to be emptied into these deep drains at suitable places.

It is here relevant to record that in the early history of irrigation in India, in areas where there are already alkaline soils, it was thought that these blankets of saline concretions would be washed away with continued heavy irrigation.

Unfortunately this did not happen. On the other hand the souring of soils with the formation of bogs, and the rendering of even fertile soils alkaline, resulted from uncontrolled irrigation. Experienced Irrigation Engineers have finally come to the conclusion that every irrigation scheme must tackle simultaneously the problem of surface and sub-surface drainage. These conclusions are amply confirmed from the observations of the Nizamsagar canal area.

In the Tungabhadra canal area in the Raichur district where there are already extensive tracts of saline zones (yielding large quantities of salt) with thick sub-strata of impervious concretionary alkaline layers, the possibility of water-logging and the formations of bogs is even greater than in the Nizamsagar area, where comparatively, conditions are not so serious as in the Raichur district. It is well to recognize at this stage that it is important to study very carefully the remedial measures that would have to be adopted for sub-surface drainage along with the development of irrigation schemes.

There is a great necessity for appointing a Special Officer with adequate staff who should be invested with powers not only to see to the maintenance of the canals and distributaries but also to exercise control over the economic distribution and utilization of water to the fields. Indiscriminate irrigation not only results in the frittering away of water resources, but in complicating problems of soil and sub-surface drainage with the introduction of water-logging. It is imperative to vest this Officer with legal powers to deal with infringement of irrigation rules.

To start with, it will be worthwhile to appoint a senior Officer assisted by a number of subordinates to deal with the investigation of the sub-surface and underground drainage and the seasonal variation of the water-table. The rate of sub-surface flow in suitably selected places will also have to be gone into carefully.

It will be advantageous to send an energetic and intelligent young Engineer to one of the important Irrigation Research Centres in India like Lahore to enable him to study the practical aspects of sub-surface drainage. On his return, he should engage himself with the tackling of the important problems of water-logging, requiring immediate attention, at the same time starting a series of observational centres to collect data to tackle the problem on a regional scale on a

scientific basis. He may be assisted by two Sub-Divisional Officers, 4 Supervisors, 8 Overseers and 10 to 12 Sub-Overseers as he has not only to tackle the problem of water-logging requiring immediate attention, but also to collect the necessary data for its extensive application in the whole area.

Here it may be worthwhile mentioning that when the Nizamsagar Canal was constructed the P.W.D. had no data before it in regard to the reaction of the soil under heavy irrigation. No doubt some canals of a lesser magnitude had been constructed before, but they were mostly seasonal ones. The conditions of soil under perennial irrigation could not therefore be visualized when the forecast was prepared. In this forecast allocation was made for the cultivation of rice in Abi and Tabi seasons, and also sugarcane. Under two seasonal rice cultivation the land remains subject to water for about 8 months in the year, whereas in the case of sugarcane the watering has to be done almost for 12 months. Actually however the sowing of rice is made not at the same time all over the area, but according to the convenience of the cultivator. Similarly in the case of sugarcane there are varieties which take even 18 months for their maturity. Thus although in some years harvesting might be completed earlier, in others, standing crops have to be supplied with water. This makes it obligatory for the distributaries and the channels to carry water for longer periods than necessary. The reason for this, in my opinion, seems to be that there is no canal act fixing the dates when water will be given and when it will be shut off. As far as I could see the Irrigation Engineer seems to be more at the mercy of the cultivator, and thus no scientific control could be exercised with regard to the use and distribution of water.

It is a well-known agricultural axiom that soil under heavy irrigation must be given periodical rest in order to recuperate its natural conditions. In the Irwin Canal of Mysore they have introduced the Block system of irrigation, similar to the Mutha canal at Poona, whereby the soil not only gets the rest but there is a lesser dosage of water which helps to reduce water-logging. In Mysore the system followed is that if sugarcane is raised on a land in one year, in the next year they have to grow rice in order to take advantage of the residual manuring. In the 3rd year the ryot has to sow dry crops such as jawari or wheat with a little watering. This system has saved lands under Irwin Canal from water-logging to a considerable extent. And yet their Agricultural Engineers have been busy right from the beginning

to devise measures for depleting the sub-soil by a system of underground drainage. Thereby several areas which were showing signs of decay have been successfully reclaimed.

If the Nizamsagar Scheme has not to prove eventually a source of destruction to the lands, by unrestrained irrigation it is necessary that the distribution of crops to be raised in relation to the soils should be determined by a joint collaboration between the Agriculture and the P.W.D. Heavy irrigation at a rush speed may yield handsome returns for sometime, but the gradual exhaustion of soil and the large expenditure which Government may have to incur later on in reclaiming water-logged lands, would, I am afraid, make the Project defeat the expectations that may have been entertained by its authors. The bogs are indeed the warning finger of nature and it is well to understand its portents.

3rd Bahman 1354 F.
January 1945

APPENDIX XV.

USEFUL EQUIVALENTS.

Area of a Triangle = ½ base x Altitude.
Area of a Circle = π x Radius²
Volume of a Cylinder = π x radius² x height.
π = 3.14159 or approximately 3 1/7.

REGULAR POLYGONS OF SIDE 'A'.

Sides	*Name*		*Area*
5	Pentagon	..	$a^2 \times 1.72$
6	Hexagon	..	$a^2 \times 2.598$
7	Heptagon	..	$a^2 \times 3.634$
8	Octagon	..	$a^2 \times 4.828$
9	Nonagon	..	$a^2 \times 6.182$
10	Decagon	..	$a^2 \times 7.7$
11	Undecagon	..	$a^2 \times 9.365$
12	Duodecagon	..	$a^2 \times 11.2$

1 inch of rain yields 22,622½ gallons of water per acre, and about 14 million gallons per square mile.

1 inch of rain yields about 100 tons of water per acre.

1 inch of rain yields about ½ gallon of water per square foot.

1 inch of rain in a year per square mile would yield if stored about 38,000 gallons per day.

1 inch of rain in a year per acre would yield if stored 62 gallons per day.

1 English acre=4,840 square yards.

1 cubic foot of water=6.23 or about 6¼ gallons, and weighs very nearly 62½ pounds (1,000 ounces), at a temperature of about 40° F.

1 Gallon of water weighs 10 pounds.

224 Gallons of water weigh 1 Ton (2,240 pounds).

1 Gallon=4.5449 litres=0.16 cubic foot.

1 cubic foot=28.317 litres=6.228 gallons.

1 Square mile=640 acres.

A column of water one foot high exerts a pressure of 0.433 pounds per square inch, or 62.352 pounds per square foot.

Degree Centigrade to degrees Farenheit ; Multiply by 9, divide by 5, and add 32.

Parts per 100,000 into grains per gallon multiply by 7 and divide by 10.

Grains per gallon into parts per 100,000, multiply by 10 and divide by 7.

Grams per litre into grains per gallon, multiply by 70.

Grams per litre into parts per 100,000, multiply by 100,

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ERRATA

Page 1. Line 19. *For* ino *read* into.

Page 31. Line 31. *For* wate rbut *read* water but.

Page 53. Line 27. *For* atotal *read* a total.

Page 62. Line 1. *For* genera lintroduction *read* general introduction.

Page . 77. Line 42 *For* marking *read* making.

Page 88. Line 16 *For* scraps *read* scarps.

Page 118. In the 5th column of the Statement. *For* 6^1 *read* 6′

Page 129. Line 8. *For* 26′ *read* 36′.

Page 138. Line 20 *For* 91 *read* 96.

Page 138. Line 14. Last column. *For* S *read* o.

Page 141. Line 7. *For* 3-8-0 *read* 4-8-0.

Page 141 Line 8 *For* 4-0-0 *read* 5-0-0.

Page 162. Line 26. *For* planat *read* plan at.

Page 182. Tabular Statement Column 2. *For* 20′, 32′, 3′, 3½ & 4′ *read* 20, 32, 3, 3½ & 4

Page 184. Item 11. Column 3. *For* do *read* lb.

Page 188. Line 22. *For* and and *read* and

Page 196. Line 8. *For* for *read* f or.

Page 207 Line 11. *For* 34,667-13-0 *read* 34,667-13-4.

Page 207. Line 32. *For* 16′ *read* lb.

Page 215. In Tabular Statement. *For* e *read* c.

Page 230. Below Table, Line 3. *For* quality *read* quantity.

Page 235. Line 17. *For* $\vdash$ *read* $\times$.

Page 244. *For* Fig. 29 *read* Fig. 30.

Page 252. Line 34. *For* in the next page *read* by the side.

Page 257. Line 5. *For* 256 *read* 259.

Page 268. The 1st statement and the 3rd statement at the bottom page are to be taken as continuous ones.